

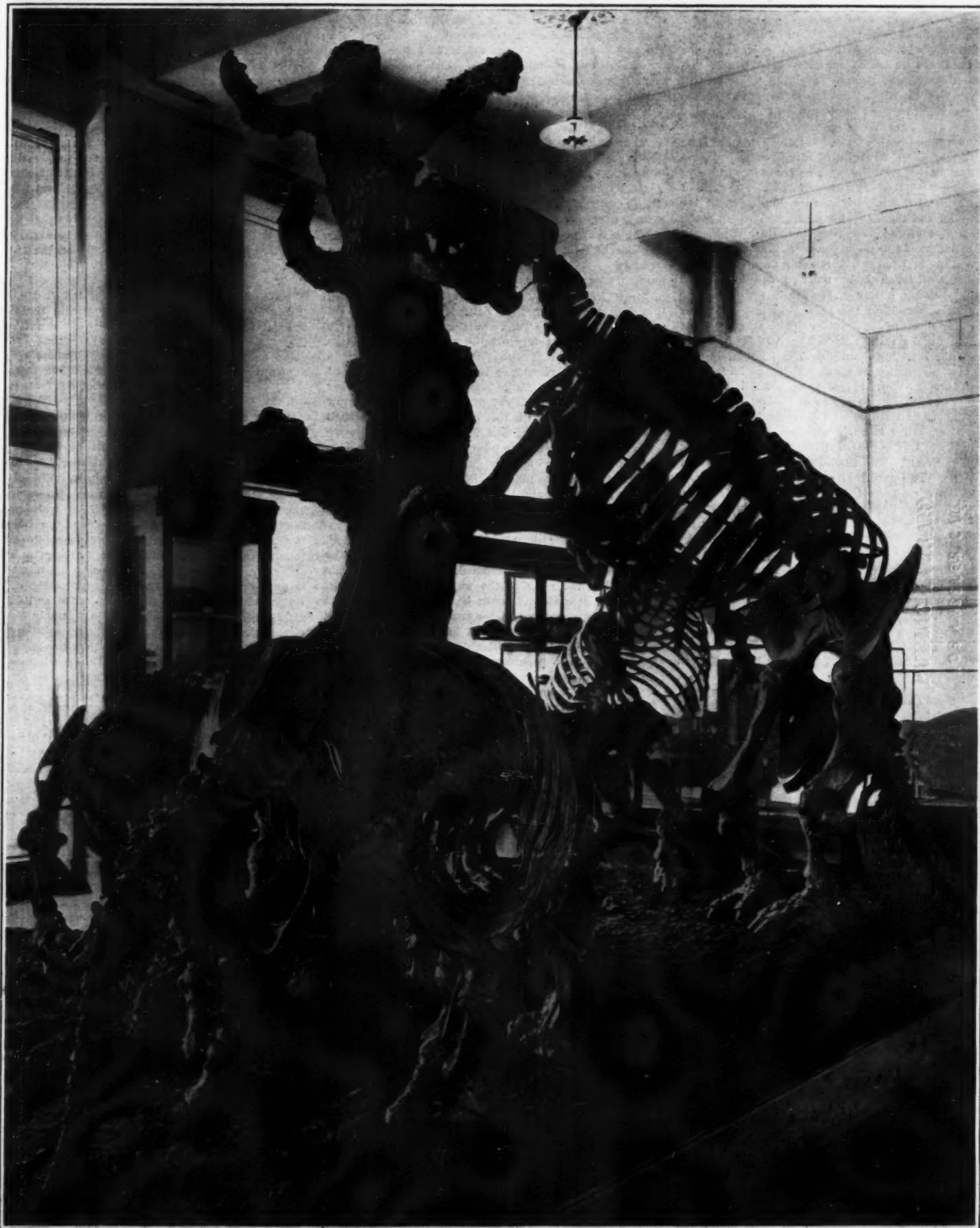
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Ogilvie Service

Group at American Museum of Natural History

Group of complete skeletons of giant sloths such as once roamed New Jersey and New York
A 200,000-YEAR-OLD SUMMER PLAYGROUND (See p. 160)

Illuminating Devices in the Great War—II

An Account of Aerial Lighting Devices and Their Development from 1914 to the Armistice

By Capt. H. M. Brayton, Ord. R. C.

[CONCLUDED FROM SCIENTIFIC AMERICAN SUPPLEMENT No. 2277 FOR AUG. 23, 1919, PAGE 127]

It will be noted from the discussion thus far that but one form of parachute shell has been taken up, the shell with the single star or illuminant. Naturally this is a shell of the intensive type. Attempts have been made to make illuminating shell of the parachute type which would spread their light over a greater area. These are known as scatter type. Within a six-inch shell body for example is placed a number of long cylinders usually of steel. Seven would be the logical number to use as these would fit nicely around the circle with one in the center. The cylinders extend the whole length of the interior cavity. Within each cylinder a small cardboard container and a parachute are placed. In the container end a charge of powder and a short delay fuse is added. The nose of the shell is filled with the powder charge as in the other design and the base plug holds them all in place. The explosion of the time fuse in the air expels the seven cylinders with their contents into the air, at the same time igniting the short delay fuse. These cylinders tumble through the air until the fuse has burned through, when the charge of powder in the top of the case is fired, expelling the parachute and container holding the illuminating mixture. The mixture must be ignited at the same time. The parachute should open and the light burn furiously. Unfortunately they do not always function as we should like to have them. It was quite unknown to get more than half of the stars to light up. Some would not come out of the steel cylinders and others would not ignite after they did come out. Here is an illustration of a too complicated design. Under practical conditions it could not function perfectly. The fundamental idea is however a good one. The parachute and container being contained in a second steel sleeve prevents it from receiving the very heavy stresses at the instant the time fuse acts in the air. By the time the fuse burns through and the cylinder contents are expelled, the velocity of the steel cylinders has been checked and the parachute may with safety be made of lighter material. It will be apparent that such a shell could utilize but a small percentage of its available space in actual illuminating material. The fact that the shell is primarily for the purpose of giving light seems to have been lost sight of here. If it could be made to function such a design might be spectacular but hardly an efficient weapon of war.

NON-PARACHUTE ILLUMINATING SHELL.

As the name implies this type of illuminating shell carries no parachute or other device for the purpose of keeping it suspended in the air or to check its downward velocity. The reader may at first wonder about this and be inclined to believe that something must be made to take the place of the parachute. The facts are however that this shell is designed for an entirely different purpose from that for which the parachute type was developed. The non-parachute shell is for very short intense illumination only and finds its greatest field of usefulness in defensive work against aeroplanes. In order to do effective shooting against night raiders it is first necessary to see the enemy planes. The parachute shell might accomplish this result to perfection but because its time of burning is so long it would be very apt to give the enemy airman valuable information about the ground over which he was flying. It might be sufficient to enable him to get the range and location of his objective, the very thing which we must do all in our power to avoid.

These facts coupled with the possibility of obtaining much better efficiency when a parachute is not used made it very desirable to develop such a shell. By efficiency we here mean the total amount of light which it is possible to get from a projectile of a certain caliber. More space is available in the shell without a parachute for the illuminating mixture.

The English have developed such a non-parachute shell which the writer will attempt to describe in a general way here. The shell is bored out straight in the same manner as the parachute shell cavity described above. The interior is filled with two layers of cylindrical containers. An ordinary three-inch shell would contain 12 or 14 of these cylinders placed say seven in a row and two rows. This number makes a symmetrical arrangement with six around the circumference and one in the center. There are voids, of course, between the containers. The cylinders are

made of cardboard or thin sheet metal and loaded with the illuminating material under high pressure. This pressure may in some cases reach 5,000 pounds per square inch. Sometimes one end of the cylinder is closed in which case the other end is loaded with a priming composition for the top layer together with a strand or two of quick match. The quick match is usually made to extend through the side of the container toward the center of the shell. When both ends are left open the lower end is also arranged with the fuse and primer. When arranged in the shell these strands of quick match extend into the voids between the cylinders. This is to insure their being caught by the flame at time of burst. The contents are held in place by means of a base plug in some designs or, in those designs which eject their contents forward, by merely screwing on the head or adaptor.

The action of the shell is as follows. Their use being limited to the air they are always fitted with a time fuse. The gunner sets this time fuse to the desired number of seconds he wishes the fuse to delay after it leaves the gun. At the time set the firing pin hits the primer thus firing the base charge of black powder in the fuse. In small shell this charge might be sufficient to eject the contents but in large caliber shell it is necessary to add more powder in some kind of a receptacle in the head to which the flame from the fuse charge may gain access. In either case there will be sufficient pressure created to throw out the contents. With this pressure within the shell there is plenty of heat and flame to ignite the loose ends of quick match extending into the voids. This must take place within the shell in order for proper functioning to take place. This quick match in turn ignites the primer and then the main charge. By the time the main charge is ignited the cylinder is well out into space and falling.

Herein lies the secret of the non-parachute shell. The container is made as light as possible and the area as large as can be conveniently arranged. This means that the ratio of the weight to the projected area of these containers must be low. The lower this ratio the more slowly will the container fall in the air because the less power it will have to overcome the air resistance and the smaller the force of gravity will be. It has now been worked out so well that one standing some distance from the point of burst of one of these shell is scarcely conscious that the stars are falling at all during the period of burning.

These stars, as they are called, should quickly light up after they are ejected from the shell. The time of burning varies considerably but is usually around 10 seconds. This is sufficient time to enable a friendly observer to get the range of the enemy craft and not time enough to help the enemy. In most cases the light would be close enough to the aviator to blind him for the instant as far as his view of the ground was concerned. The element of surprise is also important as the enemy does not know when to expect the light.

Because of the fact stated above that much more of the illuminating mixture can be placed in this type of shell and also because the time of burning is much shorter than when a parachute is used it naturally follows that the intensity of illumination is greatly increased. The time of burning can be regulated to some extent between certain limits by varying the mixture, the pressure used in loading or the amount of burning surface. The changing of the time of burning will materially affect the intensity and so the designer must select the one condition which he desires—that is, either set the time of burning or the intensity and make the other come as near to what is wanted as possible. Usually the time of burning is fixed and experiments conducted on illuminating mixtures with the view of obtaining compositions which will give the maximum light and still burn at the set time when pressed into a container. This really becomes a very complicated problem and the best chemists are required to solve it. Factors which may seem unimportant at first may later be found greatly to affect the final results. These mixtures will be discussed later in this article.

Our Ordnance Bureau had no shell of the non-parachute illuminating type when we entered the war. The parachute type was considered more important at that time and effort was concentrated upon that problem. Later however the non-parachute idea was

started and successful tests conducted. This work was conducted by the writer and his staff at the Frankford Arsenal in Philadelphia. Special credit is due former Lieutenant Colonel A. S. Cushman of Washington, D. C., who was at that time in charge of the chemical laboratory at the Arsenal and who personally supervised the chemical side of the work, bringing to bear upon the problem his great store of knowledge and experience as a research chemist. Special mention must also be made here of the excellent work of Mr. David Berger, research chemist on the laboratory staff at the Arsenal, who carried out most of the chemical experiments and materially aided the development work by his knowledge and steadfast attention to duty. The mechanical ballistic side of the problem was handled by the writer.

As the War Department considers this shell of sufficient military value to forbid the details of its construction being published it will be impossible to take it up here. It will be sufficient to state that greater efficiency has been attained than in any similar type of shell of which the writer has any knowledge. Practically 100 per cent of the space within the shell is utilized for illuminating mixture. It is unfortunate that this shell was not perfected in time to be of value on the western front. This was a special disappointment to those who worked on the problem.

ILLUMINATING MIXTURES.

The chemicals used for the illuminating mixture can truly be called the heart of the illuminating shell. If these mixtures have been well compounded for the work which they have to do the shell will be very apt to function in a satisfactory manner. The chemical part of the star shell is by far the most intricate to handle. The principal characteristics which a good illuminating mixture should have are the following: It must be reasonably cheap and procurable in quantity. It must contain no chemicals which are apt to explode or ignite either during the process of mixing and loading or during storage, due to possible chemical action. It should keep well in storage and function afterward. Ignition should be reasonably easy by means of some of the various priming substances. It must pack when subjected to high pressure either alone or when some coating is added. This coating must not seriously affect the ignition or the luminosity of the mixture.

All illuminating mixtures or compounds of a practical nature must contain two elements, fuel and an oxidizing agent. In no event must the designer rely upon the air to furnish the needed oxygen to combine with the fuel. The reason for this will at once be evident when it is recalled that this mixture must burn from a metal container the opening of which will be surrounded by burned gases which would serve very effectively to exclude the air from the surface. There are numerous such fuels and oxidizing chemicals known to chemists all of which have their characteristics both good and bad for our use. We are often obliged to choose the least of several evils when all of the chemicals of which we know contain a characteristic which we do not want present. This is one of the main factors in complicating the problem. Some of the mixtures used and tried will be given here. It does not follow that because one knows the formula all the information is at hand. The method of preparation is often of more importance in the final results.

ENGLISH ILLUMINATING MIXTURES.

The English have three standard illuminating mixtures which they use in several of their star devices. These are known as mixtures A, B and C. *Mixture A* consists of the following components:

Barium nitrate, Ba(NO ₃) ₂ ,	37%
Magnesium (coated)	34
Potassium nitrate, KNO ₃ ,	29

Here the magnesium is coated with cannabax wax or paraffin by melting the oil in a shallow pan and when hot stirring in the magnesium until the latter is thoroughly coated. The whole is then sieved and cooled. This coating serves a double purpose. It acts as an excellent binder when the mixture is pressed and also serves to prevent the magnesium from rapidly oxidizing in storage. Coating of the fuel with some kind of oil is now almost universal practice. The English were

among the first to use this method. The potassium and barium nitrates are of course the oxydizers from which the magnesium may draw its oxygen when burning. When heated both of these chemicals give up their oxygen readily. The potassium is slightly more sensitive to heat than the barium and that is why it is used here. It makes the mixture a little more easy to ignite. All potassium nitrate is not used partly because of its greater cost but also because such a mixture would be too sensitive. This mixture is very near to the theoretical proportions. What we mean by this will be explained later.

Mixture B consists of the following chemicals:

Barium nitrate, Ba (NO ₃) ₂	58%
Magnesium (Coated)	29
Aluminum (Coated)	13

Here we have aluminum used in conjunction with the magnesium but in small quantity. The reason for using aluminum is without doubt a question of cost with the English as well as perhaps inability to procure sufficient magnesium for the needs at that time. Aluminum can in no way take the place of magnesium as a fuel in illuminating mixtures. When used it usually causes trouble. It is harder to ignite and gives less light per unit weight. When magnesium cannot be secured however it makes a good substitute for certain mixtures. Aluminum alone is very difficult if not impossible to ignite in a shell. It is slow to start and the time allowed while the container is coming out of the shell in the air is insufficient and the heavy blast of air which it then receives is fatal.

Mixture C consists of the following chemicals:

Barium nitrate, Ba (NO ₃) ₂	46%
Potassium nitrate, KNO ₃	10
Magnesium (coated)	35
Sodium carbonate, Na ₂ CO ₃	3
Syrum carbonate, SrCO ₃	2
Calcium carbonate, CaCO ₃	2
Ferric oxide, Fe ₂ O ₃	2

It will at once be apparent that this is a very complicated mixture and it is doubtful whether the chemists who propounded it knew just why they put in some of these chemicals. It is too complicated for practical use. The same rule applies here as in other matters of good design. The simpler the composition the better. As a matter of fact this composition was tried out and found to be far inferior to either A or B mixtures. Essentially it is like mixture A but not as effective.

In addition to the three standard mixtures cited above the English had a few others which came to our attention. The following mixture No. 1 was used in their 2.95-inch parachute star shell and gave good satisfaction:

Barium nitrate	61.8%
Sulphur	15.9
Aluminum	22.3

This mixture was pressed into the containers at a pressure of 5,000 pounds per square inch. Mixture No. 2 consists of:

Barium nitrate	38.3%
Potassium nitrate	25.2
Magnesium (coated)	33.5
Boiled linseed oil	3.0

The magnesium was coated with 25 per cent of paraffin. This mixture was used in the English 4.7-inch non-parachute star shell.

Primers.—Both mixtures No. 1 and No. 2 require an igniter or primer as it is called. The following composition was used with Mixture No. 1:

Potassium nitrate	56.5%
Sulphur	18.5
Antimony sulphide	7.0
Meal powder	18.0

With Mixture No. 2 the following primer composition was used:

Potassium nitrate	50%
Sulphur	25.0
Meal powder	25.0

In all cases the primer is pressed in as the top layer and is usually from one-half to one inch in thickness. These primers are very sensitive mixtures and are compounded to ignite readily. For this reason they must be handled with care during the preparation process and care exercised to prevent friction enough to cause trouble. Small quantities should be mixed at a time and large amounts should not be allowed to accumulate. Disaster will result unless these precautions are taken.

Considerable knowledge was obtained concerning the illuminating mixtures used by the Germans in their star shell and other similar devices. This information

had to be obtained entirely from chemical analysis of unburned components picked up on the battlefield.

Mixture No. 1: German.

Barium nitrate	61.5%
Aluminum	20.0
Sulphur	18.5

This mixture gives a white light and it will be noted that it is the same as the English mixture No. 1 given above, except for the proportions. This composition was not efficient and was found to be very slow burning. German mixture No. 2 contained:

Cerium carbonate	8.8%
Potassium chlorate	66.9
Gum lac	16.4
Bitumen	8.0

Another German combination mixture No. 3 contained:

Potassium chlorate	55.0%
Cerium carbonate	10.0
Aluminum in scales	25.0
Bitumen	10.0

German Mixtures Nos. 2 and 3 give a red light. The aluminum in No. 3 is in the form of scales and not powdered. The scale is used to increase the area of surface and thereby increase the sensitiveness. This principle may be utilized to a limited extent in a number of the fuels used.

The following mixture was used by the Germans as a powder delay, when it was desired to make the illuminant delay a certain time before it lighted up:

Potassium nitrate	65.9%
Sulphur	8.5
Aluminum	6.1
Charcoal	16.0
Agglomerated material	3.5
Humidity	1.0

In addition to the mixtures cited as used by the English and Germans the following list might be of interest to the reader. These compositions have been worked up on a theoretical basis by the writer and show to what extent various combinations may be used. The usual way in developing a suitable mixture for a particular use is first to make a study from a purely theoretical standpoint, details of which will be taken up later, and then to try them out under actual tests. The mixtures are made up in the laboratory, pressed into containers, and burned statically. The time of burning and the illuminating effects are both noted. It is seldom necessary to do more than note this latter quality with the eye. Later if the mixture has developed sufficiently it may be desirable to measure the actual amount of light which a standard quantity of the material will give. This sort of theoretical knowledge is almost wholly lacking at the present time. During time of peace the laboratories of the country should take the problem in hand with the view of thoroughly covering the field and of obtaining complete knowledge of both the chemical and physical characteristics of all possible combinations. A few suggested mixtures follow:

Mixture No. 1.

Barium nitrate	68.0%
Magnesium (coated)	32.0

Mixture No. 2.

Potassium nitrate	63.0%
Magnesium (coated)	37.0

Mixture No. 3.

Barium peroxide	87.5%
Magnesium (coated)	12.5

Mixture No. 4.

Potassium nitrate	63.0%
Aluminum	37.0

Mixture No. 5.

Barium nitrate	76.0%
Aluminum	24.0

Mixture No. 6.

Potassium nitrate	20.0%
Magnesium (coated)	12.0
Meal powder	67.0
Rosin	1.0

Mixture No. 7.

Barium nitrate	10.0%
Potassium nitrate	35.0
Magnesium (coated)	40.0
Meal powder	10.0
Cerium fluoride	5.0

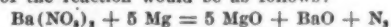
The first five of these mixtures are as simple as it is possible to make them. They contain but one chemical as a fuel and one as an oxydizing agent. This

shows how simple they may be made. The fewer chemicals the better, because there are less different ones to purchase and less trouble involved in the preparation.

PROPORTIONING MIXTURES THEORETICALLY.

In order to be theoretically perfect the mixture should contain just enough oxygen to burn completely the fuel present. If there is an excess of fuel present it is a waste because, as stated above, the air must not be relied upon to furnish the extra oxygen. If oxygen is present in greater quantity than needed it is also a waste. The oxydizing agent is, however, sometimes added in extra amount in order to quicken the mixture. If oxygen is in excess the fuel has a better chance to unite with it, with the result that a more sensitive composition will be had. This is where practice varies from theory. It cannot be inferred however that theory is not of value because of the necessity of practical experiments later. Theory gives the chemist a point from which to start his experiments without which he might experiment for an indefinite time with no results to show for his work. Theory, then, gives the starting point from which the experimenter may work both ways until the most satisfactory practical results are attained.

Mixtures are proportioned theoretically merely on the basis of their atomic weights and their molecular weights. An illustration will help to make this clear. Let us assume the mixture No. 1 as given directly above. We desire to find the proportions of barium nitrate and magnesium. In this simple calculation we will neglect the paraffin coating on the magnesium. For a close study this should be considered but usually this refinement is not necessary. The chemical equation of the reaction would be as follows:



The molecular weight equation may be written thus

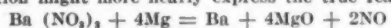
$$258.4 + 5(24.3) = 5(40.3) + 153.4 + 2(14)$$

We may then write a proportion between these values. If we let Y equal the per cent of nitrate we have the following

$$(5 \times 24.3) \div 258.4 = (100 - y) \div y$$

Solving $y = 68.0$ per cent and $100 - y = 32.0$ per cent the amount of magnesium in the composition.

There are other methods of arriving at the same result but this is one of the simplest when it is possible to write the equation. Chemists may differ concerning the way in which certain chemicals will react as for example in the above mixture the following equation might more nearly express the true reaction,



in which case the proportions would be somewhat different. What actually takes place is in many cases a matter of opinion. The temperature of combustion is so high in many cases as to be outside the range of chemical knowledge. Such a theoretical study will in any event help to get us started on the right track and many times very good results may be obtained without change in the proportions.

THEORETICAL HEAT STUDY OF MIXTURES.

The temperature obtained by the burning of these illuminating mixtures is extremely high, so high in fact that it would be impossible to measure them except with an optical pyrometer. The actual temperature obtained in the air is naturally much lower than the theoretical—how much lower we have no way of determining. The factors of radiation, conduction and convection at those temperatures and in varying air conditions have not been determined. We wish we might have information of this kind as it would be a great aid in selecting illuminants. It is a well known fact that temperature is necessary in the production of light. There are of course exceptions to this rule as in the case of phosphorescent substances. Generally speaking however the amount of light which we may expect to get from a substance is proportional to its absolute temperature. With this in mind would it not be of value in the study of such mixtures to know the maximum temperature which could be produced by any given composition? Such a study would, to be sure, show us only relative values but in this way a comparison could be made between the different mixtures under consideration. It is only necessary to assume that the radiation, conduction, etc., are the same for all mixtures when they are burned in the air. This assumption is probably not far from the facts.

We really have two values to determine, namely, the temperature of the combustion and the quantity of heat in actual B. T. U. given off when a certain weight of the mixture is burned. It does not follow that the mixture which gives off the greatest quantity of heat will have the highest temperature. The specific heat of the various chemicals must be considered when the

(Continued on page 155)

Selecting Wood for Airplanes

A Discussion of Considerations Necessary in Selecting Materials and the Effects of Some Hidden Defects

By Arthur Koehler*

WHAT kinds of wood should we use in airplane construction? Where and how shall we get the material? How shall we select the individual pieces?

The Forest Products Laboratory, of the United States Forest Service at Madison, Wisconsin, was asked by the Army and Navy Departments to solve these questions immediately after the beginning of the war. This laboratory had the fundamental information with which to work out quickly answers to questions one and three. The Spruce Production Division of the Air Service and the lumbermen answered question two.

Prior to the entry of the United States into the war 130,000 strength tests on 130 native species had been made at the Forest Products Laboratory. These had covered strength in shear, tension and compression parallel and perpendicular to grain, bending, hardness, resistance to shock, cleavage, etc., and tests had covered the same species in the green and air-dry conditions. Work had also been done to determine the effect of standard defects on strength.

It is proposed in this article to discuss some of the considerations necessary in selecting the lumber for

SIZE AND SHAPE OF PIECES.

The checking of dimensions is important principally on finished pieces, but also has a bearing on the inspection of lumber itself. Faulty manufacture or seasoning may reduce dimensions of a piece so that it has no value for an intended purpose. This is illustrated by an incident which occurred in the work of a certain inspector of finished parts. He found that wingbeams after being routed out were scant in the up and down dimensions along those parts where the sides were routed out, but of full dimensions at the strut points, which are not routed. This was found to be due to case-hardening of the beam, a fault in seasoning, and wherever the greater portion of the sides of the wing beams had been removed the internal stresses were relieved and the stick shrunk in vertical thickness. The instruction of inspectors included among other things methods of drying and of determining defects due to improper seasoning.

DENSITY.

It is not enough to specify a certain kind and dimension of timber where a maximum amount of

stick in bending and compression, and these strength properties may be tripled by careful kiln drying. All strength properties are not influenced equally in removing the moisture from the wood. For instance, average tests on many woods show that the maximum strength as a beam or a post increases about 4 per cent for every 1 per cent decrease in moisture near 12 per cent moisture. The stiffness, however, increases only 2 per cent with every 1 per cent decrease near 12 per cent moisture; and the toughness or shock-resisting ability actually decreases slightly in most species as the wood dries.

The influence of moisture on strength is more important in airplanes in its effect on the shrinkage or swelling of the parts (especially of propellers), because the parts usually dry out or absorb moisture and come into equilibrium with atmospheric conditions before the machine is put into flight. The shrinkage which may take place in too wet woods after they are machined may seriously loosen fastenings, and causes the pieces to be under size.

Shrinkage or swelling are often accompanied by



Fig. 1—Compression failure occurring during growth in African mahogany

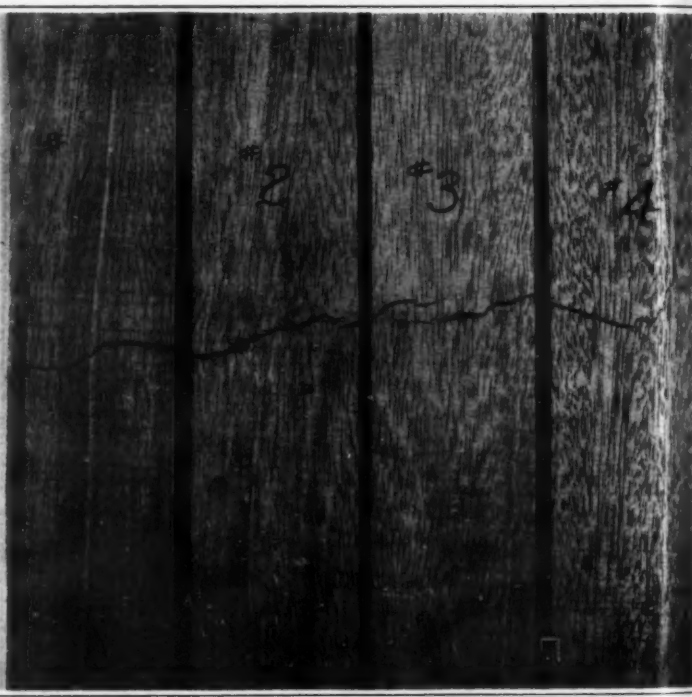


Fig. 2—Influence of the failures of Fig. 1, under static bending

making up airplane parts, and to leave the discussion of tests on finished parts for future articles.

SPECIES OF WOOD.

Maximum strength per unit weight is a primary requirement for all wood used in airplanes. In most cases it is most desirable to use a fairly light wood; in a few cases, however, such as tail skids and the front portions of longerons, heavier woods are used. In these two specified cases, the ability to steam-bend well is of great importance. For propellers, the ability of the wood to stay in place with atmospheric changes is of very great importance. For most of the structural members of aircraft, woods like spruce and Port Oxford cedar have proved very satisfactory. When heavier, harder woods are needed, and when they must be steam bent, ash and elm are usually used. Propellers are made of a variety of woods, such as poplar, oak, ash, mahogany, and walnut.

All of these woods are in demand for other purposes as well as for airplanes, and their expensiveness tends to promote substitution. Accurate identification of the wood is therefore essential, and the preparation of simple keys and the actual instruction of inspectors in the fundamentals of this work was undertaken by the Forest Products Laboratory at the request of the Signal Corps and continued throughout the war. Classes usually consisted of from twelve to twenty men and lasted from two weeks to a month. One hundred and two inspectors were trained at the laboratory.

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strength is desired. One piece of ash may be only half as strong as another of the same size and species. Wood grows under widely different conditions of soil, moisture, sunlight and exposure, and it is only natural that considerable variation exists in its properties.

Results of tests at the Forest Products Laboratory show a definite relation between the strength and dry weight, or density, of wood. Strength varies with weight. Therefore specific gravity is the best indication of strength except an actual test. A test usually spoils a piece for further use and gives information on only a few mechanical properties. For example, a test on bending tells no more of hardness or end-compression strength than the specific gravity indicates.

Tests at the Forest Products Laboratory, however, have checked the theoretical relation between the stiffness and the maximum strength of slender struts. In these tests the stiffness is determined without stressing the strut beyond its elastic limit.

Place a beam on two horses, jump on it, and if it does not break it is satisfactory. This was a not uncommon test in the industries. Under such a test the beam was often stressed beyond the elastic limit and was permanently weakened even when not broken.

There are methods of judging the quality of timber by examining the end grain and noting the width of rings and proportion of summerwood, but these methods are far less reliable, especially in hardwoods, than the density test.

MOISTURE CONTENT.

An air-dry stick containing about 12 per cent moisture has almost double the strength of a similar green

warping, which may seriously distort a piece. Springing such a piece into place may cause assembling stresses which may lead to trouble. One of the most common troubles with propellers is the warping due to change in moisture content.

METHODS OF DRYING.

It has been known for a long time that certain methods of kiln drying do not produce as strong wood as other methods. The expression "the life has been taken out of the lumber" is common among woodworkers. Two factors are mainly responsible for this condition:

1. Too high temperatures in the kiln. It is well known that wood heated until it is charred is brittle and brash. Extremely high temperatures such as are sometimes maintained in a dry kiln seem to have a similar but, of course, less drastic effect. Tests on wood properly dried at various temperatures show that temperatures below 150°F. have no weakening effect on the wood if it is otherwise properly dried.

2. The other cause of reduction in strength in kiln drying is case-hardening, which causes checking (the checks may be so fine as not to be visible in ordinary inspection) and stresses.

The statement that the strength of wood has been reduced in kiln drying does not mean that the wood comes out of the kiln weaker than it went in, but rather that it comes out not as strong as it might have been if dried under more favorable conditions. Lumber practically always comes out of a kiln stronger than it was when it entered, except in toughness or

shock-resistance. It has been found that its toughness is not load bearing, but will hold together.

Wood is under stress, and expects to be one way or the other.

Wood is under stress, and expects to be one way or the other.

Wood is under stress, and expects to be one way or the other.

Some in the mean may be the method.

Among the failures of the material.

The defects of the material and size of the defects.

ends, near the middle of the beam.

All the advances in the method.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

Blue wood is also a blue stain.

shock-resisting ability and possibly in resistance to shear along the grain. The expression "The life has been taken out of wood" means that it has lost some of its toughness; that is, it will not bend much under a load but breaks off more or less abruptly, although it will hold more of a load before it breaks than it would when green.

DEFECTS.

Wood, unlike steel, is not made according to a formula under uniform conditions, and therefore we must expect more or less variations and defects. In fact, one writer on aeronautics makes the statement that one reason why wood is used in airplanes is that the defects present are readily visible on the surface.

source of danger because they are very weakening, yet difficult to detect. Care must be taken to detect fine lines or wrinkles running across the grain, such as shown in Figures 1 and 2. These are due to the timber having been bent at some time, either by wind or in rough handling, so that the fibers on one side have become compressed or wrinkled.

One or two worm holes here and there are not serious, although care must be exercised to see that they are not worse than surface inspection would indicate and that they are not accompanied by decay.

One of the most obviously weakening defects is diagonal grain. In order to bring out the fact that the grain may slope on the tangential face as well as on

stick having a slope of the grain of 1 in 25 is somewhat weaker than one in which the grain runs straight, and that a slope of 1 in 20 is slightly weaker than a slope of 1 in 25; but that a slope of 1 in 15 is much weaker than a slope of 1 in 20. This applies to special grain as well as to diagonal grain, and to Douglas fir as well as Sitka spruce.

Occasionally curly and wavy grain, which are local irregularities in the grain of the wood, are found. These also may be either on the radial or tangential faces. Again, any such irregularity is more difficult to see on the tangential face than on the radial face, where it is indicated by the direction of the annual rings, as waves or dips. Here also the curly grain, as



Fig. 3—Tangential faces of spiral grained spruce. Note fine resin ducts and the "check" parallel to them.



Fig. 4—Failures due to diagonal grain. A grain slope of 1 in 15 is much weaker than a slope of 1 in 20.

Some inspectors may not agree with this. But what he meant was that in steel defects may be present or may be developed, as in the case of crystallization of the metal, and yet not be readily visible.

Among the more common defects in wood are knots, rot, shakes and checks, pitch pockets, compression failures or crossbreaks, worm holes, spiral and diagonal grain, and curly and wavy grain.

The detection of knots gives no trouble; to estimate their seriousness is more difficult. The weakening effect of knots depends on their size, soundness, location, and size of the stick they are in. If a stick is subjected to bending, knots are most weakening on the convex side in the portion midway between the two ends, next on the concave side, and least at the ends or midway between the two surfaces in the center of the beam.

All users of wood are familiar with decay in the advanced stages where the wood crumbles to the touch; it is the early stage of decay which is hard to detect but which is dangerously weakening. To be on the safe side an inspector should regard all abnormal discoloration of wood with suspicion, for discoloration either darker or lighter than the normal wood is one of the first visual indications of decay. Of course, there are irregularly colored streaks in the heartwood of some woods which are not due to decay, as in cirsian walnut, red gum, ash, and others.

Blue stain is not decay and does not in itself weaken wood although the conditions which are favorable for blue stain, namely, wet sapwood and warm weather, are also excellent for decay, only decay is slower in its action. Blue stain may hide evidences of decay, and for that reason should be rejected in airplane parts.

The separations of the fibre known as shakes and checks are objectionable because they reduce the resistance to longitudinal shear. The shearing strength of wood cannot be expected to increase any in seasoning unless very carefully dried, because checks, possibly only microscopic checks, may develop which reduce its resistance to shearing forces parallel to the grain.

Pitch pockets are found only in the pines, spruces, Douglas fir, and tamarack. They are weakening in small pieces such as are used in airplanes, because they deflect the grain, producing local diagonal grain or dips, and also because they reduce the resistance to longitudinal shear.

Compression failures, or crossbreaks, are a grave

the radial face it is necessary to distinguish the two forms of cross grain as spiral grain and diagonal grain respectively. The two are about equally weakening when of the same slope, spiral grain being slightly more dangerous in some species. This is due to the fact that where wood fails on account of spiral grain it splits across the rings, along the medullary

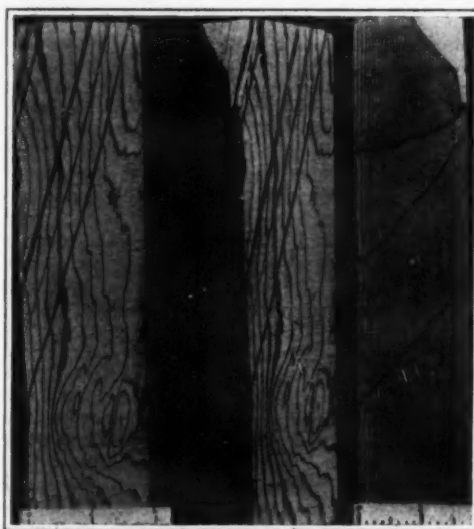


Fig. 5—Failures in spruce due to spiral grain; splitting across annual rings.

rays, which is a slightly weaker plane than that tangent to the rings.

Unfortunately it is much more difficult to detect spiral grain than diagonal grain, and here is where a thorough knowledge of the structure of wood is essential. Without this knowledge it is difficult to distinguish between resin ducts, pores, medullary rays and abnormalities or discolorations that might be confused with the grain.

Shortly before the cessation of hostilities, the Forest Products Laboratory completed a test on 1,800 spiral and diagonal grained pieces of Sitka spruce and 875 Douglas fir pieces, including slopes from straight to 1 in 3. These tests show that on the average a

seen on the tangential face, may be more serious, because the fibers may cross the piece almost at right angles to the sides. This might occur where a knot had healed over. Such extreme local slope, however, is rarely found in the annual rings on the radial face. A chain is no stronger than its weakest link nor a strut or wingbeam than its weakest part, and such defects therefore must be carefully searched out and eliminated.

The use of wood for airplanes has without doubt brought to engineers and designers a greater appreciation of the fact that, when properly chosen, wood has advantages for certain uses which cannot in practice be duplicated by metals or other materials. It has also demonstrated the value of research bearing on the properties of wood.

Was This an Aerial Tornado?

In a note recently received from Prof. J. Mascart a striking cloud phenomenon seen in north-eastern France on July 8, 1918, is described. At 7:25 p. m. (Summer Time) a wide belt of thin cirro-cumulus cloud had formed over the sky, and in this belt was traced out in the course of a few seconds a loped curve consisting of a roughly circular loop with two arms extending from it. The shape somewhat resembled the figure 6, but with the end of the ring continued out to the left hand. The curve, of a width of about a semi-lunar diameter, was marked by a complete absence of cloud in the otherwise uniform cirro-cumulus sheet, clear blue sky being visible throughout its length. The circular ring, which was somewhat flattened, was of about 20° diameter, and at an elevation of about 60-70° above the western horizon. The phenomenon remained visible for twenty-five minutes until the cloud-sheet evaporated. During this period the cloud drifted slowly from south-west to north-east, and the looped curve appeared to maintain its position unchanged relative to the cloudlets. Prof. Mascart puts forward the interesting suggestion that the clear path through the cloud which formed the curve was caused by the passage of a small cyclone (tornado?) or whirl in the upper layers of the air, which by mixing caused the cloud-particles to evaporate. It thus left a track through the cloud similar to that which a tornado marks out for itself on the earth by its path of destruction. A drawback to this hypothesis is the great speed at which the curve was generated.—*Nature* (London).

temperature of the fruit will fall at a rate depending on the dimensions, spacing, and thermal conductivity of the fruit, and the condition of the air in the cooling chamber, until an equilibrium is reached after two or three days. This equilibrium temperature lies, however, one or two degrees higher than that of the chamber. This temperature difference is a characteristic of the different fruits, so that soft fruit which matures most quickly shows the greatest difference. As respiration must be the cause of this constant heat production in the fruit, there must be a definite relation between the respiration number and the temperature difference. The temperature difference increases after a certain time of storage, for instance, in apricots it is 0.7°C. at the commencement of storage, while after four to five weeks it is 1°C. Thus a very simple and convenient means might be found for indicating when the time has arrived to remove the fruit from the store, as experiment would show at what temperature difference it becomes inadvisable to keep fruit longer.

It is easy to understand that it would be possible to keep the temperature in the cold store for fruit below zero, partly on account of this temperature difference, and partly because the freezing point of the fruit lies a little below 0°C., namely between -1° and -2°C. It has indeed been the tendency in the history of the cold storage of fruit to use lower and lower temperatures. The first temperatures used were 5° to 10°C., later it was found that fruits kept longer if kept at from 4° to 5°C., while now temperatures about zero are very generally used, but it is scarcely generally realized that it is possible to go still lower without any danger of freezing the fruit.

Thus there is not much scope for varying the conditions in the cooling chamber as regards temperature. The other factors which allow of variation are humidity, light, and movement of air, but in respect to these, conditions have to be worked out independently for each species, or even variety. Generally speaking, for soft fruits, which are easily destroyed by fungi, it is preferable to have a moderately dry atmosphere which is kept in motion, while for stone fruit and apples which shrink owing to loss of water, it is preferable to have moist and still air. In regard to illumination a diversity of opinion exists, some writers urging complete darkness and others a high light intensity.

As the value of some fruits depends on specific aroma due to the presence of volatile acids or alcohols, cold storage may be of no commercial value in these cases unless special precautions are taken to prevent evaporation such as by wrapping the fruit in paper or dipping it in a liquid which easily solidifies and covers it with a protective glaze.

(To be continued)

Researches on Fog-Signal Measurement*

Canada has been among the most progressive of maritime countries in the experimental development of fog-alarm systems. The type of fog-alarm which has found favor in Canadian waters, and has been installed in many localities, is a modified form of compressed-air siren, known as the "diaphone." The original diaphone was invented by Dr. Owen Hope-Jones. Its utilization for fog-alarm purposes was first suggested by Lieut.-Col. Anderson, Chief Engineer of Department of Marine and Fisheries of Canada, who with his chief assistant, Mr. B. H. Frazer, determined from numerous tests the lines along which the diaphone evolved into full-sized fog-signal apparatus in the hands of Mr. J. P. Marthey of Toronto.

Although powerful sirens have been in use in all maritime countries for nearly half a century, there was until recently comparatively little accurate information available regarding the way in which sound waves were actually generated in such apparatus. It has long been known that existing types of sirens or steam whistles are extremely inefficient; that is, little of the power furnished is converted into sound of such a character or quality as will penetrate a desired distance in foggy weather. The extent to which it is possible to protect a trade route in this way from accidents due to fog depends ultimately on the power, penetration and reliability of the fog-alarms which can be installed and operated at a given cost. The difficulty in the development of what may be called "acoustic engineering" has been the almost total lack of sound-measuring instruments.

From the work of Lord Rayleigh, Webster and others, it was known that the proportion of power converted into sound with musical instruments was exceedingly small, in many cases less than one part in a thousand. It was found that the sound from a diaphone unprovided with a trumpet was extremely com-

plex, and that the effect of a trumpet of correct design was to concentrate a greater proportion of the power into the master tone. During propagation through the atmosphere, the overtones do not travel far but are filtered out, the master tone surviving to an appreciable extent at distances greater than two miles. It is now possible to state in horse power or watts the total acoustical output of a siren as well as to compute the relative proportion of power expended in the master tone and overtones. That this may be done as a test is of great importance, as the designer will now be able to predetermine the behavior of fog-signal apparatus without having the equipment installed at great expense at some station by the sea.

Variation of Physical Properties of Iron Alloys With Composition and Treatment

THE material tested by E. Gumlich consisted of dynamo iron from various sources, in the compact form and also in cylindrical bars and thin sheets, also alloys containing C, Si, Al, and Mn. The properties tested were those of density, resistivity, position of the first and second critical temperatures, and especially the magnetic properties by means of hysteresis cycles and losses, coercive force, remanence, initial and max. permeability, and saturation value. In general, the effect of thermal treatment on density and resistivity is small, and only of importance in the C and Mn alloys; on the other hand it strongly affects the magnetic properties by removing the mechanical and magnetic hardness produced by the rolling of the metal. Further, heating causes the C and O contained in the metal to combine in the form CO which is then driven off. A molecular deterioration is at the same time introduced. The best heating temperature found was 800°. Electrolytic iron gave magnetization curves which could be altered at will by thermal treatment; slow cooling after heating gave a steep magnetization curve with relatively high max. permeability, but with smaller hysteresis loss. After repeated heating, this sensitiveness disappeared, and the final curve lay far down, the remanence being 850 and coercive force 0.15 gauss. Such material would be useful for cores in electrical measuring instruments which have had to be made hitherto without iron on account of the remanence of the latter. In the case of the alloys, extrapolation gave for zero content of alloyed metal, 4. e. for pure iron, density 7.876, resistivity 0.0994 ohm per meter/mm.² at 20°, resistance temperature coefficient 0.57%. Addition of Si and Al causes a great increase in resistivity and in the Al alloys the temperature coefficient is much diminished. As regards magnetic properties, carbon plays the most important part. It enters in three ways: as graphite in the tempering process when it is magnetically almost neutral; as iron carbide Fe₃C (cementite and pearlite); and as dissolved carbon (martensite). The last two cause a lowering of μ and an increase of hysteresis loss, and coercive force amounting to 7 gauss in pearlite and 70 gauss in martensite per 1% carbon. In the latter form which appears during rapid cooling, carbon impurities of a few thousandths per cent. cause great deterioration in magnetically soft metal and must be kept out at all costs. On the other hand, the properties produced are useful in permanent magnets. With increase in dissolved carbon coercive force increases but remanence diminishes; it is here that additions of W, Mo, and Cr have a good effect. Increase of carbon causes a decrease in the temperature coefficient of magnetic moment, and permanent magnets have been made with 1.4% C, and hardened at 1,000°, which had no temperature coefficient. Silicon alloys have been much used for transformer material on account of their high resistivity and consequently smaller eddy-current losses; they have also good magnetic qualities in low fields. But the addition of Si diminishes the magnetic quality of pure iron. The improvement effected by Si is of a secondary nature; with 4 to 5% Si the carbon impurities do not remain in solution, but are separated out in the form of pearlite which again, by long heating and slow cooling, can be transformed into the innocuous form of graphite. Additions of Al have a similar effect although, probably owing to technical imperfections, the good results obtained with Si have not been reached. By heating at 1,100°, the remanence of the 10% alloy of Al is reduced to 1,500. The magnetic qualities of Mn alloys have not yet found an application in practice. They are similar in some respects to the carbon alloys; in certain circumstances the coercive force rises to 130 gauss (C alloys, 70 gauss), but the simultaneous drop in remanence excludes their use as permanent magnets. In contrast with the C alloys, quenching makes the metal magnetically softer. With between 8 and 10% Mn there are sudden changes in the density, resistivity, coercive

force, and saturation value which are caused by the appearance of austenitic constituents. These cause total disappearance of susceptibility in alloys of 14% Mn and over. With increase of Mn content, the A_{c2} point sinks from about 760° to 600°, and the A_{r2} point sinks much further so that in the 12% alloy it lies much under ordinary temperature. A specimen can thus be produced either in the magnetic or non-magnetic condition according as it has been previously heated above A_{c2} or cooled. These two forms have different densities and resistivities. The transition from the austenitic to the martensitic state takes place suddenly, and is frequently perceptible as an audible crack. The whole process is similar to that which obtains in the irreversible Ni-steels which are now so extensively used in the manufacture of armour plating.—Sci. Abstr.

How Graphite Forms in Iron-Carbon Alloys

WITH a view to throwing light on the actual mechanism of the formation of graphite in iron-carbon alloys, Kunichi Tawara and Genshichi Asahara, of Tokio University, Japan, recently placed before the Iron and Steel Institute a paper on the results of an investigation by them and carried out at the expense of G. Aikawa. An abstract follows:

"As the presence of impurities such as silicon and manganese influences the formation of graphite, the iron on which the experiments were made was prepared from pure magnetic iron-sand found in Western Japan (Tyôgoku), an analysis of the sand revealing the following low percentages of other elements than iron: Carbon, 0.15; silicon and silicic acid, 0.08; phosphorus, 0.01; sulphur, 0.01 per cent with a trace of manganese. Copper was entirely absent. Some 27 samples of iron were prepared from this sand by melting in a Morgan crucible with hard charcoal, the attempt being made to keep the charcoal in the final ingots at 3, 3.5, and 4 per cent, and while this did not prove practicable the percentage in no case exceeded 3.93, and in only two out of the 27 samples fell below 3 per cent.

"The alloy obtained was a white iron containing practically nothing but iron and carbon, the percentage of silicon in no instance exceeding 0.06 and being in many cases as low as 0.01 per cent. The authors, therefore, justly claim that the formation of graphite must have been determined in all the experiments solely by the physical conditions under which the samples were cast. These conditions were represented by the temperature reached in the melting, which was effected in a gas furnace; the temperature at the moment of running; the temperature of the mold; the time occupied in cooling; and the method of cooling. The temperature of the melt ranged from 1,274 to 1,436 deg. C.; the casting temperature from 1,233 to 1,399 deg. C., while the temperature of the mold was kept at 1,100 deg. C., except in three instances, one of which was a chill at 50 deg. C. The time taken in cooling ranged from 1/2 hr. to 8 hr.; generally 1 1/2 hr. was given as slow cooling, in one case 3 hr. slow cooling was given, while in others the metal was kept at about 1,000 deg. for 8 hr. (7 1/2 once owing to accident) and then quenched in water, while in another the metal, immediately upon being cast, was quenched in water.

"The authors carefully examined the resulting ingots micrographically and chemically. Their conclusions may be generally summarized as follows: Graphitization can take place even when the total carbon present is as low as 2.18 per cent; the amount of carbon present when ranging between 2 per cent and 4 per cent is not a decisive factor in graphitization; the variation in the melting temperature within the range of the experiments appears to have no effect; graphitization does not take place at such a temperature as 900 deg. C., even if maintained for several hours; it may occur at 1,000 deg. C., but the most favorable temperature, as used in the experiments, was 1,100 deg. C.; under the latter temperature there is no appreciable effect on graphitization whether the cooling begins directly after the cast or after an annealing time of three hours has elapsed.

"The difference of slow cooling and water quenching is not a serious factor in graphitization; in other words, the graphite crystals are not likely to be produced in the later stages of cooling, but at the same time the quenching may limit the graphitization, while slow cooling may favor it. In setting out their theory of graphitization, the authors assume that cementite is always present in molten iron-carbon alloys, and that as it is a compound its constituents may dissociate in the molten state into iron and carbon, and that, even though the dissociation may be small, the carbon atoms set free may serve as the nuclei upon which the graphite crystals are built when the conditions are favorable."—The Iron Age.

*Abstract in Jour. Franklin Instit., of report by L. V. King in Bull. 2, Ottawa, of Canad. Adv. Coun. Sci. and Indust. Research.

Experimental Wireless Telegraphy and Telephony—V*

Describing the More Advanced Types of Receiving Sets, with Particular Reference to Post-Bellum Practice

By Louis Gerard Pacent and Austin C. Lescarbours

THE advent of vacuum tubes, sometimes called electron tubes, has resulted in great advances in radio communication. As such tubes may be used for a variety of purposes, to generate, to amplify, and to modulate radio oscillations, as well as to detect them, they are now used in many types of radio apparatus. New applications have come rapidly, and possibilities of further development are most promising. One fact of importance is that such tubes make possible the use of apparatus that is easily portable—a primary consideration that is often important. The principles underlying the uses of vacuum tubes, and their operation under the widely different conditions met in actual practice, therefore deserve careful study. An entire instalment of this series is devoted to vacuum tubes,

(negative electricity) is established from the filament to the plate.

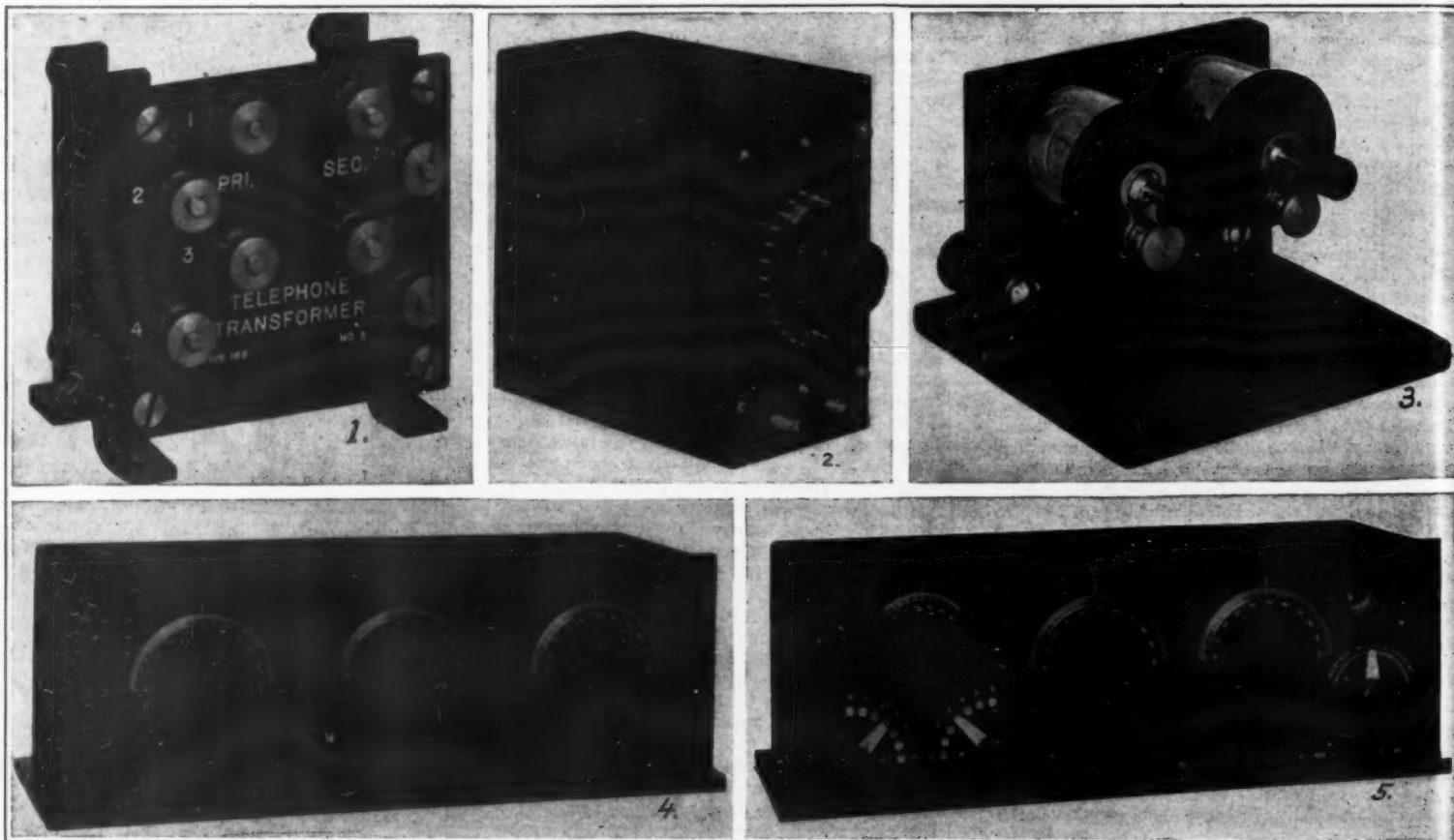
The three-electrode vacuum tube, which is the type most generally used today, is a great improvement over the two-electrode type. It differs in the addition of a third electrode, inside—and sometimes outside—the tube in the form of a metallic gauze or "grid" of fine wires between the filament and the plate. This makes it possible to increase or decrease the current between the filament and the plate through wide limits, in a manner described in another section.

Suffice it to say here that vacuum tubes are obtainable in various forms and sizes for use as detectors, amplifiers, modulators, and generators. At present it is the vacuum tube for reception and amplifying pur-

expected that he is dissatisfied when he returns to his own car.

The receiving apparatus described in the previous instalments was pre-war material. Today the apparatus used by most amateurs is comparable with that of commercial stations, both in operating efficiency, workmanship, and appearance. Indeed, the same apparatus has been made for the American and other governments.

For one thing, everything operates with a rotary movement in the better types of present receiving apparatus. Sliders are no longer used. The old single- and double-slide tuning coils are replaced by variable inductors known as variometers, which consist of two coils one of which is stationary and the other rotative.



1.—Telephone transformer for use in vacuum-tube circuits. 2.—New type of loading coil which takes the place of the long tubes and sliders of pre-war days. 3.—Modern double crystal detector unit, with switch for connecting either detector in a circuit. 4.—Tuning unit, consisting of a variable condenser and two variometers. 5.—A short-wave regenerative receiving set, comprising a loose-coupler, two variometers, a vacuum-tube holder, and a rheostat for the vacuum-tube filament. Note the rotary adjustments of this set, which typifies the present high-grade amateur apparatus.

Representative instruments now being used by advanced radio amateurs and experimenters

but it is well here to touch briefly upon the subject in connection with advanced receiving apparatus.

VACUUM TUBES AS DETECTORS.

There are two general types of vacuum tubes in common use for detecting radio signals, namely, the two- and the three-valve tubes. The two-valve, sometimes called the Fleming valve, is an earlier form containing an incandescent filament and an electrode or plate. Normally, when the filament is cold, no current can flow between the electrode and the filament, or across the vacuum which separates them. But once the filament is heated it is possible to pass current through the vacuum. The action of this and other forms of vacuum tube depends upon the fact that when a metal is heated in a vacuum, it gives off electrons into the surrounding space. As the electrons have a negative charge, the charge remaining on the metal is positive, therefore few of the electrons go very far, but are attracted back to the metal so that there is a kind of balance established between the outgoing and the returning electrons. When current is caused to flow between the two elements, however, a continuous flow of electrons

poses that interests us most. There are numerous vacuum tubes regularly used in receiving and amplifying signals, among them the DeForest, General Electric, Western Electric, Donle, Marconi, and others. However, so far as amateur use is concerned there is but one tube available, namely, the Marconi, at present.

A WORD ABOUT POST-BELLUM APPARATUS.

The calling of tens of thousands of wireless amateurs into the Army and Navy radio service has naturally had its result on amateur wireless in the United States. Thus, before the United States entered the war, the average wireless amateur was well satisfied with a crude wireless set. The tuning coil might be two feet long, hand-made, and provided with several crude sliders which sometimes made contact and sometimes did not. The condenser might be a set of crude plates sliding between an equally crude set of fixed ones. All in all, appearances counted for little, as might also be said of operating convenience.

But then when these same young men became acquainted with commercial apparatus, they soon forgot the old hand-made apparatus back home. And why not? If a man has been riding about in a cheap automobile and then suddenly is permitted to use a five-thousand dollar car for several months, it is to be

By moving the rotative coil it is possible to increase or decrease the inductance of the two coils, and thus change the inductance in a given circuit so as to tune a receiving set.

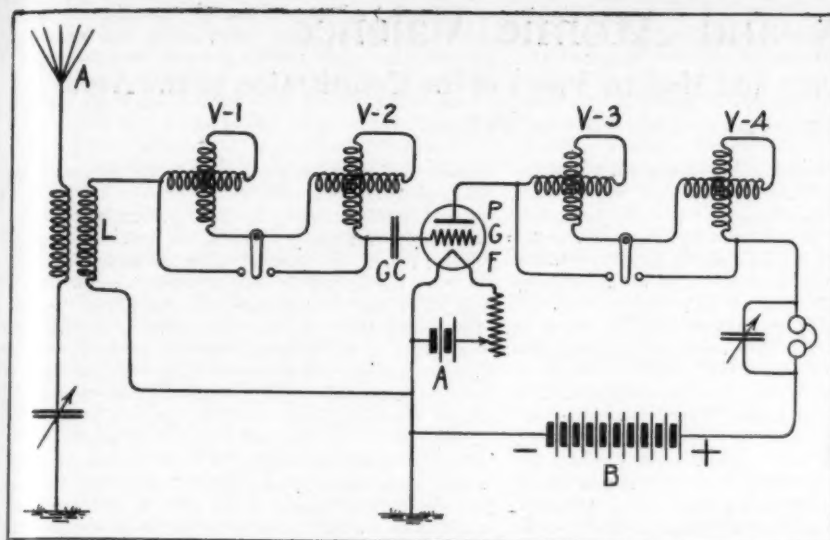
There is one disadvantage, however, that must be admitted about variometers when exclusively employed for tuning, namely, that the wave-length ratio of the receiver is only $2\frac{1}{2}$ to 1, and for tuning to a greater range it becomes necessary to use two variometers, one set of low inductance and one set of high, with a wave-length switch to cut in either set. The arrangement of the apparatus is shown in the first of the accompanying sketches.

The sliding secondary type of loose-coupler is not altogether out-of-date. However, the rotary coupling type is fast coming into use. In this instrument there are two coils, a fixed one and a rotative one, after the fashion of the variometer. The adjustment of the rotative coil can be determined at a glance by a calibrated scale on the handle of the instrument.

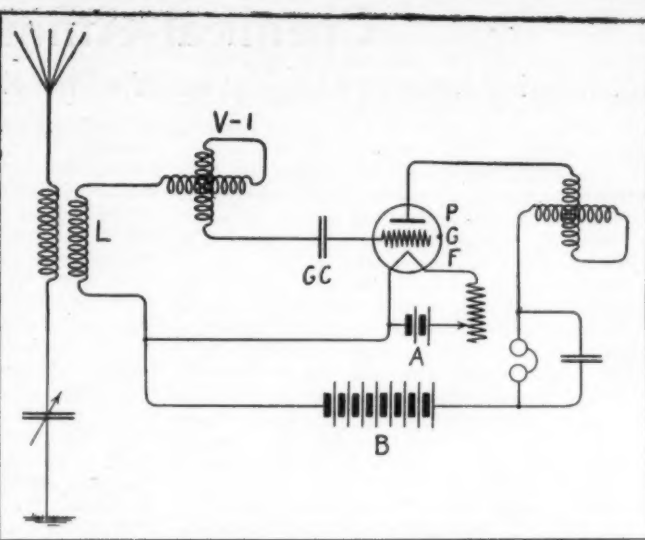
As for variable condensers, the rotary type remains in use, because its rotary action is in accordance with the ideals of today. However, the condensers are now made so that the capacity is in proportion to the rotation.

The old carbon button and other designs of microphones for amplifying signals have been abandoned

*The first article of this series appeared in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 2270, dated July 5, 1919. Copies of back numbers containing this series may be obtained as long as the supply lasts. (Copyright, Scientific American Publishing Company, 1919.)



Wiring scheme for using two variometers, one of low inductance and the other high



Regenerative set in which the tuning is done with loose-coupler, variometer and variable condenser

for the simpler vacuum tubes. The microphone amplifiers do not stop at amplifying signals but go right ahead and amplify external noises, so that little is gained. Today, however, compact audio frequency amplifying vacuum tubes are used with excellent results.

REGENERATIVE RECEIVING.

With the discovery of the regenerative action of vacuum tubes by Edwin Howard Armstrong, while experimenting with radio as a so-called amateur, came the big boom in radio communication as practiced by commercial, Governmental, and experimental interests.

The great discovery of Armstrong, who has served as Major in the U. S. Signal Corps in charge of radio research in the A. E. F., permits the use of one vacuum tube as an amplifier, detector, and oscillator at the same time, and thereby increases the sensitivity of the usual receiving station many times. This is done by using a few additional instruments and carefully connecting these in accordance with correct theories.

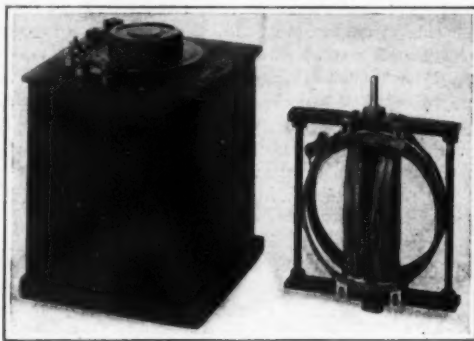
Major Armstrong discovered that the current flowing in the plate circuit of a three-electrode vacuum tube is oscillating in character and not a straight direct current, as was always taken for granted by scientists and experts in that particular branch of the wireless art. It was found that this oscillating plate current, which oscillated on the positive side only was in exact resonance with the incoming oscillation for which the receiving circuit was tuned. So it occurred to Armstrong that if he increased the amplitude of the oscillations in the plate circuit, he would get a louder response in the telephones. He accomplished this by coupling the plate circuit or output to the grid circuit or input, much after the fashion of placing a telephone receiver against a transmitter to produce a shrill note. This regenerative coupling produces amplified grid oscillations, which, by means of the grid, produce greater variations in the plate current, thus still further reinforcing the oscillations of the system. Simultaneously with this amplification the regular detecting action goes on, and the final signal in the telephones is not in proportion to the original signal strength, but is the final amplitude of the oscillations in the plate circuit.

There are two general methods by which a vacuum tube can be made to regenerate. First, an auxiliary coupling—either electromagnetic or electrostatic—can be used between the plate and the grid circuits, whereby the energy of the plate circuit oscillations may be fed

back to reinforce the grid circuit oscillations. Secondly, placing an inductance coil in the plate circuit of a simple tube receiver and so adjusting it with respect to the capacity of the vacuum tube that the plate circuit becomes resonant. When this condition is approximated the high frequency oscillations in the plate circuit react on the grid circuit through the medium of the coupling of the vacuum tube, thereby greatly increasing the strength of the grid current.

The second method is particularly suitable for the reception of short waves and therefore ideal for experimental radio communication, both because of the amplifying properties and because of the simplicity of adjustments. The accompanying diagrams show a regenerative circuit embodying an electromagnetic coupling for simultaneously amplifying and rectifying received signals, and a regenerative circuit using an electrostatic coupling.

Inasmuch as the vacuum tube is a voltage-operated device, the best results are obtained with a small condenser and large inductance in the grid or secondary circuit; in fact, a condenser can be dispensed with and



Typical variometer, showing exterior and interior construction

the tuning accomplished entirely by means of the distributed capacity of the coils and the capacity of the tube.

In order to eliminate dead ends and obtain the highest efficiency, the grid and plate inductances must be continuously variable. They are best made in the form known as variometers, already referred to, and used in the manner shown in the fourth sketch.

Whether to use separate instruments or complete receiving sets is a question that varies with the requirements of every radio amateur and experimenter. For those who simply wish to receive signals, the complete receivers are no doubt most applicable. But in instances where experimentation is to be carried on, with all manner of circuits for determining how best to receive signals, the amateur and experimenter should turn to the so-called unit instruments, or separate pieces which can be "hooked up" to suit himself.

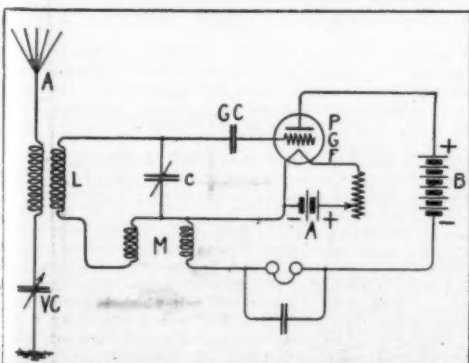
Among the better types of complete receivers now available are the short-wave and long-wave regenerative sets the description of which is left to the next instalment, for lack of space in this issue. Amplifiers will also be described at length in the next instalment, particularly those whose wiring is most ingenious and whose operation is of the simplest. A later chapter is devoted to the subject of vacuum tubes and their characteristics.

Proposed Hydraulic Experiment

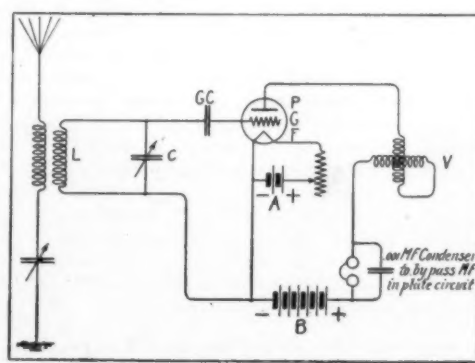
In an early paper (1850) Stokes showed "that in the case of a homogeneous incompressible fluid, whenever $u dx + v dy + w dz$ is an exact differential, not only are the ordinary equations of fluid motion satisfied, but the equations obtained when friction is taken into account are satisfied likewise. It is only the equations of condition which belong to the boundaries of the fluid that are violated." In order to satisfy these also, it is only necessary to suppose that every part of the solid boundaries is made to move with the velocity which the fluid in irrotational motion would there assume. There is no difficulty in the supposition itself; but the only case in which it could be readily carried into effect with tolerable completeness is for the two-dimensional motion of fluid between coaxial cylinders, themselves made to rotate in the same direction with circumferential velocities which are inversely as the radii. Experiments upon these lines, but apparently not quite satisfying the above conditions, have been made by Couette and Mallock. It would appear that, except at low velocities, the simple steady motion becomes unstable.

But the point of greatest interest is not touched in the above example. It arises when fluid passing along a uniform or contracting pipe, or channel, arrives at a place where the pipe expands. It is known that if the expansion be sufficiently gradual, the fluid generally speaking follows the walls, or, as it is often expressed, the pipe flows full; and the loss of velocity accompanying the increased section is represented by an augmentation of pressure, approximately according to Bernoulli's law. On the other hand, if in order to effect the conversion of velocity into pressure more rapidly, the expansion be made too violently, the fluid refuses to follow the walls, eddies result, and mechanical energy is lost by fluid friction. According to W. Froude's generally accepted view, the explanation is to be sought in the loss of velocity near the walls in consequence of fluid friction, which is such that the fluid in question is unable to penetrate into what should be the regions of higher pressure beyond.

It would be a difficult matter to satisfy the necessary conditions for the walls of an expanding channel, as the travelling bands of which the walls would be constituted should assume different velocities at different parts of their course. But, as a rough approximation, two wheels revolving in opposite directions are suggested in the hope some one will make the test.—RAYLEIGH (*Phil. Mag.*)



Regenerative circuit using electromagnetic coupling



Regenerative circuit using electrostatic coupling

Chemical Affinity and Atomic Valence*

Relation Between Chemical and Thermal Energy and Modern Views of the Constitution of the Atom

By G. Ciamician and M. Padoa, University of Bologna

I. THE general laws of affinity are independent of the qualitative difference of matter; they have been discovered and applied without the aid of the atomic hypothesis and the latter indeed might appear to be superfluous for the representation of the most essential portion of chemical phenomena. The atomic hypothesis, in fact, did not seem indispensable for the explanation of the phenomena of chemical affinity, so long as the stoichiometric laws alone confirmed it, and so long as atoms were considered to be the elementary, ultimate and inalterable particles of matter. But at the present time the question has assumed an entirely different aspect; certain ingenious researches which have been made in some branches of physics and the discovery of the radio-active bodies have lent to the theories of the granular constitution of matter the new and unforeseen support of experimental confirmation; in short, we are forced to believe in the actual existence of atoms and of molecules as a logical consequence of all the facts known to us. Furthermore, the atom can no longer be considered as the simplest primordial particle of matter but rather as an element of matter having a highly complex internal structure; for this reason the problem of affinity presents itself to us in an entirely different fashion: Hitherto it was possible to make an abstraction of the atomic hypothesis and this is what was done in fact when we confined ourselves to general laws such as are derived from the application of the second principle of thermodynamics; today, since we must regard atoms as physical units of which we cannot make an abstraction, it seems indispensable, on the contrary, to regard them as actually and essentially concerned in chemical phenomena. The latter depend upon the intimate constitution of the atoms, in which we naturally find the origin of the qualitative differences of matter connected with chemical forces. Affinity is a form of energy which, according to fundamental laws, can be transformed directly and reversibly into heat or into electromagnetic energy.

The relations which exist between chemical and thermal energy are derived from the principles of thermodynamics; it will be of value to investigate the significance which these relations may acquire if we adopt modern views concerning the constitution of atoms. According to the kinetic theory all movement of atoms ceases at the point of absolute zero, at which point their calorific capacity seems, therefore, to be annulled. The internal energy of atoms, on the contrary, does not disappear at extremely low temperatures, as is demonstrated by the phenomena exhibited by radio-active bodies and by the experiments of Moissan concerning solid hydrogen and fluorine which still react violently.

If we accept the kinetic theory it is not difficult to understand that chemical actions, measured by the rapidity of the reaction, will be proportional to the degree of concentration and will be accelerated by elevations of temperature. But as was proved by Van't Hoff, the temperature also exerts an effect upon chemical equilibrium, especially in cases of dissociation. At this point we may enquire what is represented by the absorption of heat in these reactions as well as in endothermic processes in general. It is evident that this absorption of heat measures the transformation of the external movement of atoms in movements of their intimate constituents, or, to give a general expression, to this thesis, in internal atomic energy, which energy is also capable, of course, of assuming the potential form.

If we did not assume this variation of the internal energy of atoms in endothermic compounds, it would become necessary to suppose that the formation of bonds between atoms occasions an expenditure of energy and this would not agree with the various electromagnetic representations which may be conceived for atoms themselves. In our opinion the formation of bonds between atoms occasions a development of energy in endothermic compounds as well as in exothermic compounds; but in the case of the former this energy would not be sufficient to compensate for the expenditure required to augment the internal energy of the atoms which are combining. It results from this that the algebraic sum of the energies brought into play in these combinations is negative.

According to the kinetic theory, heat results from the kinetic force [force vive] of atoms or of molecules in vibration or in translation: a reversible process in which the chemical energy which is transformed into thermal energy may be represented by a mechanism according to which the progressive or vibratory movement of atoms is transformed in a reversible manner into potential energy or into internal movement of their constituents. In other words we may say that the free energy of atoms is the fraction of their internal energy which is capable of becoming external in the form of heat or in any other form without the decomposition of the atom.

II. If we assume, as it seems necessary to do, that chemical affinity is a function of the internal energy of atoms, it would be interesting to seek the determining cause in a more precise manner. The most diverse hypotheses have been formulated along this line, but we shall not attempt to analyze them here.

We may assume not only the existence of electrostatic attraction, which the atom is capable of either by the loss or the reception of electrons, but also of electrostatic attraction between neutral atoms, if we adopt the ingenious ideas of Rutherford and of Bohr. These authors suppose that an electron revolving around an atom with a small positive mass in its center, is capable of exerting upon another positive ion or atom electrostatic actions which are opposite and dependent upon the distance at which it is situated. This viewpoint is also sustained by Crehore, who has sought to demonstrate how with such a scheme it is possible to construct formulas, especially of organic compounds. Finally, to mention only the principal hypotheses, Ramsey has attempted in his last work to explain chemical actions by the electromagnetic attractions which result from the reciprocal action of the circuits formed by the orbits of electrons and which may differ according to the direction of the rotation around the atom.

It is our opinion, furthermore, that to comprehend the essential part of the chemical phenomenon it is not sufficient to take into consideration electrostatic or electromagnetic attractions alone; whatever the theory one may formulate with respect to the nature of chemical affinity, we believe it is necessary to consider a coefficient which must be especially made manifest even though it may be comprised implicitly in some one of the hypotheses which we have mentioned above. This coefficient is related to the character of the chemical phenomenon which has always served to define it as a whole and which resides in the change—sometimes slight but often very great—of the properties of a compound with respect to those of the components.

When we examine the matter minutely it seems hard to believe that two bodies, no matter how small they may be—two atoms, for example—can undergo an essential change of their properties merely because they are placed in new conditions of reciprocal attraction. The chemical phenomenon is of very special nature and cannot reside solely in an exchange of attractions. This constitutes a weak point which has enabled the adversaries of the atomistic theory to reject the ancient hypothesis of Dalton because it could not explain the differences which exist between the properties of free elements and those of their compounds. Today, thanks to the famous experiments of Bragg we know that the atoms in crystals are merely juxtaposed; in a crystal of sodium chloride, for example, the two kinds of atoms alternate in the crystallographic network and the molecules mingle with each other in a regular succession of atoms of sodium and of chloride. What would be the difference between the crystalline sodium chloride and a mixture in which the same number of atoms of sodium and of chlorine were arranged with the same regularity?

It seems to our mind, therefore, logical to believe that the essence of the chemical phenomenon is a modification of the internal structure of the atom; this modification which the atom undergoes at the moment of combination may involve either a loss or a gain of energy. The atoms in the molecules are juxtaposed,

indeed, but their internal structure is no longer the same as in the free atom.

These modifications of the internal structure may determine attractions of electrostatic or electrodynamic origin; and if it is difficult to reconcile the two facts that we can always extract an element again from a compound and that an atom does not appear to exist in a combination with all its properties, the difficulty disappears if we imagine that the structure of the atom is modified at the moment of the combination, and that it regains its original state when the element becomes free once more. For the present we have no knowledge of the real nature of these changes. The different hypotheses which have been formulated in recent years concerning the possible structure of atoms are certainly of great value, but are still far from being able to solve the problem. Nevertheless, the studies of J. J. Thomson and of Crehore, the experiments made by G. Newton-Lewis, and above all, the marvelous experiments and deductions of Moseley, blaze the way towards such a solution.

As things stand at present, and in order to take into account the nature of these transformations of the internal structure of atoms at the moment of combination, it may be useful to compare them to a certain extent, to metamorphoses of organic compound such as those of the indicators [indicateurs] in salification. We now know that in this case the indicator is not salified by simple ionization, remaining unaltered meanwhile, but that its internal structure undergoes a change and is re-established when the indicator returns to its original state by means of the inverse operation. In the same way the expulsion or the acquisition of an electron at the moment of combination, must be accompanied by a more or less profound internal transformation of the atom; this enables us to comprehend the actual difference which exists between the atom and the corresponding ion, a difference which the mere presence of an electric charge does not suffice to explain, in spite of all that has been said

*A change of the internal structure of atoms in combination explains naturally and convincingly why the properties of a compound may be different from those of the elements which it contains. Nevertheless, the following objection to this method of regarding the question might be preferred: while certain properties of the atom change when it enters into combination others persist, as if the atom existed unaltered in its compound. The specific heat in the solid state, the refractive power, etc., have an "additive" character, and this is particularly true of radio-activity, which is not influenced by the chemical combinations. But in the consideration of the last mentioned property we may find an argument with which to make reply to the objection offered above. As a matter of fact, temperature, which exerts a very great influence upon the state of combination, exerts none at all upon radio-activity, at any rate within the bounds of our present knowledge. Furthermore, the quantities of energy brought into play in ordinary combinations are much inferior to those which are inherent in the phenomena of radio-activity. We may hold the opinion, therefore, that the transformation of the atom which we suppose to be accomplished when it enters into combination does not involve those constituents of the atom which determine the physical properties mentioned above, and we may hold likewise that a modification of these constituents would compromise the existence of the atom. By way of a comparative example it may be recalled that in the case of certain organic compounds a change of structure slightly modifies both physical and chemical properties: these compounds include the open-chain bodies and the corresponding alicyclic compounds, the paraffines and the cyclo-paraffines. We may also call attention to the heats of combustion which are almost equal for certain isomers.

*Phil. Mag., 1914, 26: 792, 1044; 27: 747.

*Phil. Mag., 26: 25; 29: 310.

*Jour. the Am. Soc., 1916, 762.

*Phil. Mag., 1914, 26: 1624; 27: 703.

*An excellent resumé of this question has been prepared by W. P. Harkins and E. D. Wilson, Jour. Amer. Chem. Soc., 1915, 1396.

*Apropos of this it may be recalled that colorless phenolphthalein for example, changes first of all its internal structure when its molecule comes in contact with a base R.OH when becoming transformed into an acid having a violet-red color, which afterwards combines with the base in becoming salified.

If a stronger acid H.N be afterwards added the original phenolphthalein will be reconstituted, but we do not have merely a simple double exchange in this instance for the colored acid which separates out becomes transformed by an internal metamorphosis into the colorless original pseudo-acid.

In the same way when di-methyl-amido-azo-benzol, which is a yellow base is salified with an acid H.N, the salification determines a change of structure, since the compound of the quinonic type is more stable; the salt which is formed is no longer nitric, but quinonic and of a red color. By adding a stronger base we may occasion the inverse reaction, which will regenerate the yellow nitric compound.

*Phil. Mag., 26: 476, 557; 29: 332; 30: 394.

*Phil. Mag., 1911, 21: 669; 27: 488.

*Phil. Mag., 30: 613.

*Proc. Royal Society, London, Series A, 28: 451.

*Translated for SCIENTIFIC AMERICAN SUPPLEMENT from Le Jour, de Chim. Physique (Geneva).

upon this subject. We can now readily conceive that an atom (or a molecule) can acquire an electric charge without becoming thereby chemically different from an electrically neutral atom, just as, for example, ionized air does not differ from non-conducting air.

The atom becomes an ion by losing or gaining energy according to the nature of the internal transformation which it undergoes (Independently of the hydration which may accompany the phenomenon) and it will remain more or less stable itself according to the greater or less degree of stability present in the new state. This greater or smaller stability of the internal constitution of the ion with respect to that of the atom corresponds to what has been rather vaguely called the intensity of adhesion of the ion to its charge. The greater or lesser tendency of the atom to acquire the structure of the ion corresponds in its turn to what is called the tension of the electric solution of the elements which is expressed numerically in the electrochemical series. Furthermore, the variation of structure in an atom which becomes an ion—accompanied according to our hypothesis by a variation of internal energy—may possibly explain the origin of the heat of ionization, particularly the positive heat which it is difficult otherwise to comprehend.

III. The nature and physical significance of valence has been the subject of the most diverse hypotheses. The theory of dissociation caused that of valence to assume a new aspect: according to the law of Faraday the valence of an atom is determined by the number of electrons which it may lose or acquire. Among those who have helped to throw light upon this concept is J. J. Thomson, who supposes that the attractive actions determined by the valences are exerted not in a spherical field, as in the case of other attractions but solely in the direction of certain lines or channels of force to which he now attributes a cylindrical form; these channels of force through which atoms exert the attractions of valence may be regarded as corresponding in some sort to the marks (short straight lines) by which chemists represent the units of valence, without, however, giving to them any special physical significance.

Making an abstraction of the nature of these attractions, which, as we have said above, may be of different origin, we believe that our idea may be expressed by saying that the number of affinities at the disposal of an element in its combinations, depends upon what may be termed the external form of the atom. We have arrived at this conclusion by studying the results of the researches made by Bragg. As we know, the crystallographic net-work of the diamond is so constituted that each atom of carbon is connected with four other atoms along lines running from the center to the apices of a tetrahedron. This fact corresponds in a most surprising manner to the tetrahedral arrangement of the valences of the carbon atom, to which chemists have had recourse to explain certain isomerisms of organic compounds; we think it logical, therefore, to believe that carbon functions as a tetra-valent element in its compounds, since its atom assumes a tetrahedral form. But this does not imply, obviously, that the free atom will have the same form. We believe this manner of interpreting the valence of atoms can be generalized and applied to the other elements. But if we accept the hypothesis we are confronted by two possible interpretations: must we believe that the form of atoms varies in the different types of combination, or assume that it remains constant? The question may be considered from the following point of view: Certain elements retain the same chemical habit throughout the different types of combination. For example, oxide of carbon, hydrocyanic acid and the carbamides, tri-phenyl-methane and the more complex analogous compounds do not differ essentially from the corresponding compounds of carbon in which the atom acts as tetra-valent. By analogy we may say that the oxygenated compounds of chlorine possess common chemical characteristics in spite of the different amounts of oxygen contained, and the same thing is true of the compounds of nitrogen. On the other hand certain other elements undergo so great a change of character in passing from one type of combination to another that one might think that the same atom consists of two or more different elements. Thus the knowledge of cupric salts could not enable us to predict the existence of the cuprous salts; and how remarkable does thallium appear because of the great difference which exists between the thallous and the

thallic compounds! The same thing is true of the compounds of manganese, if we compare the manganic and the permanganic acids with the manganous salts; or in the compounds of chromium, the derivatives of chromic acid with the salts of the sesqui-oxide.

When we take into account such facts as these, it seems necessary to believe that in the case of some elements the form of the atom may vary according to the type of the combination and consequently that there are elements whose atoms are polymorphous. In the case of some of them, such as carbon, for example, the variation of the valence does not imply the modification of the form of the atom, for the valences remain free; in the case of others different forms of the atom correspond to different types of combinations; for example, the atom of copper is dimorphous.

In the case of additional compounds when complex ions are formed according to the law of Werner, the atoms and the entire molecules which enter into play constitute new polyhedrons with greater or lesser variations of energy and of internal constitution. The chemical value of these new polyhedrons is given, as we know, by the difference between the valence of the element and those of the co-ordinated groups. We cannot make an absolute distinction between the double salts and the complex salts, but there is a gradual passage from one to the other. It does not seem to us to be necessary or even useful to suppose that the atomic attractions are of diverse origin in order to explain the existence of compounds of this type. It would be preferable to say that affinity has always the same origin, but that its intensity diminishes in proportion as the atomic or molecular complexes become greater. The Wernerian stereo-isomerism may properly serve to demonstrate the idea that the valences of complexes are of the same nature as those of atoms. We can then compare a Wernerian complex to a large atom and it might happen that it existed in the free state if we adopt the hypotheses formulated for ammonium and the substituted ammoniums. As for the a-valent compounds (neutrons) such as tri-nitro-tri-amino-cobalt $\text{Co}(\text{NH}_2)_3$, we can compare them to the atoms of the

indifferent gases of the argon series. Modern concepts of the structure of crystals continually make more manifest the relations which must exist between isomorphism and the form of atoms and of molecules. It can be at once understood from what has just been said why certain elements are capable of yielding different series of isomorphous derivatives according to the type of combination; thus at the atom of thallium, for example, will have in its monovalent compounds a form similar to that of the alkaline metals in their salts, and likewise similar to that of aluminum in trivalent compounds. The type of combination often determines the relations of isomorphism between elements of different character, because of the fact that their atoms are themselves polymorphous.

Finally, it should also be observed that in the relations between the radio-active elements and their latest products of disaggregation there have recently been discovered facts of great importance which agree with the views set forth above; two or more atoms having the same structure and the same form may be identical in their properties, even if the quantity of matter which they contain is slightly different (isotopic elements) and reciprocally two elements may be different in spite of possessing an identical atomic weight, i. e. when containing equal quantities of matter if their structure and their form are different.

Hence the properties of elements are not a function of their atomic weight alone as was believed by Mendeleeff but also of their intimate structure.

Saving by Skip-Stops

DATA are given from tests made with gasoline and electric cars concerning the energy-saving made possible by "skip-stops." The statement made by Government engineers that 10 to 16 per cent. saving could be made by skip-stop operation is confirmed by these tests. The percentage increase in power consumption on comparative stops was as follows:

	Car A	Car B	Car C	Car D
Stops every 600 ft., over no stops	89%	187%	96%	24%
Stops every 300 ft., over no stops	148	213	167	66
Stops every 300 ft., over 600 ft. stops	31	82	37	33

Cars A and B were double-truck cars, weighing 47,060 lbs. and 39,520 lbs. respectively. Car C was a single-truck car, weighing 28,740 lbs., and car D, a 5-passenger automobile, weighing 3,320 lbs. empty.—*E. J. Burdick, in Electric Railway Journal.*

Illuminating Devices in the Great War

(Continued from page 147)

temperature is determined. The following calculation adapted from Lissak's "Ordnance and Gunnery" will show how these values are obtained.

Notation: Q_{mp} = Heat given off by a molugram of the mixture at constant pressure and surrounding temperature t . That is, the difference in heat between the right and left hand side of the equation.

Q_{mv} = Heat, etc., as above at constant volume.

N_1 = Number of unit volumes after expansion to normal atmospheric pressure and 0°C.

For heat developed we have,

$$(Q_{mv} = Q_{mp} + 0.572 N_1 \quad (1)$$

Then for one kilogram of the mixture or substance we have

$$Q_{total} = \frac{Q_{mp} \times 1,000}{\text{Total Mol. Wt.}} \quad (2)$$

For temperature obtained we have,

$$Q_{mv} = C_{mv} t_1 \quad (3)$$

Where C_{mv} = Molecular specific heat in small calories. t_1 = Rise in temperature in degrees Centigrade. Equation (3) would hold true if the specific heat of the products were constant. This is not quite true however as the specific heat increases with the temperature according to the following law,

$$C_{mv} = a + bt_1 \quad (4)$$

If we assume 15°C. as the initial temperature, then $t = t_1 + 15$, (5)

The following table gives values for the constants a and b for a few gases:

Gas.	a	b	C_{mv}
CO_2 and SO_2	6.26	0.0037	$6.26 + 0.0037 t_1$
H_2O	5.61	0.0033	$5.61 + 0.0033 t_1$
Gases without condensation	4.80	0.0006	$4.80 + 0.0006 t_1$

Values of a are the molecular heats of the gases in small calories; values of b are the increments of the mean molecular heats for each degree rise in temperature.

By combining equations (3) and (4) and multiplying Q_{mv} by 1,000, since Q_{mv} is in small calories, we have,

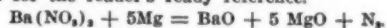
$$1,000 Q_{mv} = at_1 + bt_1^2 \quad (6)$$

This equation is a quadratic and when we solve for t we obtain,

$$t = \frac{-a + \sqrt{a^2 + 4,000 b Q_{mv}}}{2b} + 15,$$

where t equals maximum theoretical temperature in degrees centigrade produced when the mixture burns.

As this method of temperature and heat determination may be a little confusing to the reader at first it will be well to give an illustration. Let us take the same mixture which we used above, viz., barium nitrate and magnesium in the proportion of 68 to 32. The chemical equation of this reaction will be given here again for the reader's ready reference.



The heats of formation of these substances are given in the following table:

Barium nitrate	.....	229	Large calories per molugram
Magnesium oxide (MgO})	.....	143	" " "
Barium oxide (BaO})	.....	133	" " "

Specific heats are:

Magnesium oxide	.....	10
Barium oxide	.....	10
Nitrogen	.....	4.8

The heat equation may now be written as follows,

$$229 + 0 = 5 \times 143 + 133 + 0,$$

and the difference between the right and left hand side of this equation will be found to be 619 calories. In addition to this there is 0.572 large calories saved per molecular volume (22.4 liters) by the nitrogen not expanding. As there is but one part of nitrogen in the above reaction we have for the total heat,

$$Q_{mv} = 619 + 0.572 \times 1 = 619.6,$$

and then

$$Q_{total} = (619.6 \times 1000) \div (262 + 121) = 1620, \text{ large calories per kilogram, at constant volume.}$$

The theoretical temperature of this same reaction may be obtained by substituting the known values in equation (7), thus:

$$t = \frac{-64.8 + \sqrt{(64.8)^2 + 4,000 \times 0.0006 \times 619.6}}{2 \times 0.0006} + 15 = 8840^\circ \text{C.}$$

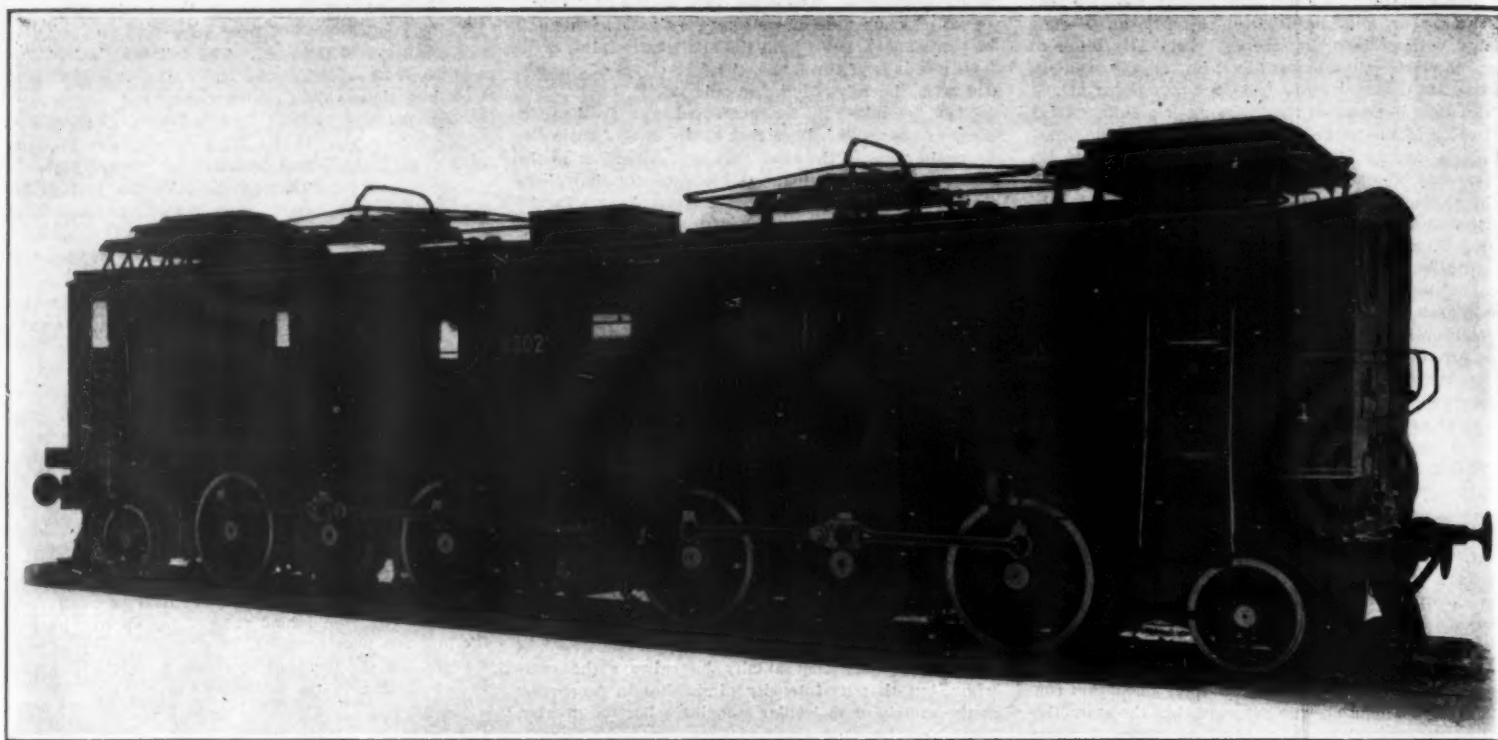
The values of a and b were obtained in the following manner:

$$a = a_1 + a_2 + a_3 \dots = 5 + 10 + 10 + 4.8 = 64.8$$

$$b = b_1 + b_2 + b_3 \dots = 0 + 0 + 0.0006 = 0.0006$$

(Continued on page 159)

¹In the network (reticulum) of the diamond according to the researches made by Bragg, the double connection (liaison) does not exist; the structure is alicyclic, so to say; on the other hand condensed benzolic rings constitute graphite and amorphous carbon, whose oxidation generates mellitic acid. A similar explanation may be given of the various allotropic forms of the other elements.



General view of the new electric locomotive of the Swiss Federal Railways. These engines now haul the trains of the Thun-Lötschberg-Simplon lines and the Bevern-Filisur section

Swiss Railways Extend Electrification

By S. Dossenbach

Photographs furnished by Swiss Information Bureau, New York

THE acute shortage of coal occasioned by the war has brought the introduction of electric traction on the lines of the Swiss Federal Railways into great prominence and in these latter years the subject has received the foremost attention of the authorities. It has now emerged as a very practical economic question.

The principal nerve of the Swiss railway system is Government owned. The electrification of these lines is simplified by the vast store of unused water power which the country possesses. According to an official survey, verified in 1914, including the stowing and improvement of lakes, the water power of Switzerland is capable of producing an energy equal to 2,173,000 horsepower. If old plants were replaced by new ones it is even estimated that the highest efficiency of the total water power reserves could be raised to as much as 8,000,000 horsepower. On January 1, 1914, the electric power already in use in Switzerland amounted to 887,000 horsepower.

The Swiss Confederation owns some 1,800 miles of the entire railway system of the country which covers 3,216 miles. Of the 1,416 miles owned by private companies 622 miles are already electrical, but only an insignificant percentage of the Government railroads has so far been operated by electricity.

The first important Federal standard-gauge road to

be chosen for electrification was the Gothard Railway, one of the important international highways, featuring moreover in many sections the brilliantly conceived engineering of mountain railways. The electrification of the 68 miles section Erstfeld-Bellinzona was approved in 1913 and it is expected that it will be opened this fall. This section, with 28 per cent of its length consisting of tunnels and a grade of 2.5 to 2.7 per cent for 25 miles, was chosen for an experiment because of its enormous traffic with Italy, which caused large consumption of coal with resulting smoke in the tunnels.

The sections Bellinzona-Chiasso and Erstfeld-Lucerne are expected to follow in 1921 and the consulting experts have found that the big power stations at Amsteg and Ritom, the first yielding 26,000 horsepower and the latter 32,000 horsepower, will also suffice for these lines, even if the traffic should increase some 60 to 70 per cent. Another series of plants yielding 70,000 horsepower is planned for eastern and central Switzerland.

The cost of electrification of the Erstfeld-Bellinzona line is estimated at \$8,000,000. The cost of electrifying the entire Federal railway system is estimated roughly at \$200,000,000.

In 1918 the electrification of the following railways using steam traction was decided upon and work on them commenced at once: the sections of the Federal Railroads Sion-Brigue and Berne-Thun; the section Hasle-Langnau of the Emmenthal Railroad and the

(Continued on page 158)

Oerlikon Locomotives for Switzerland*

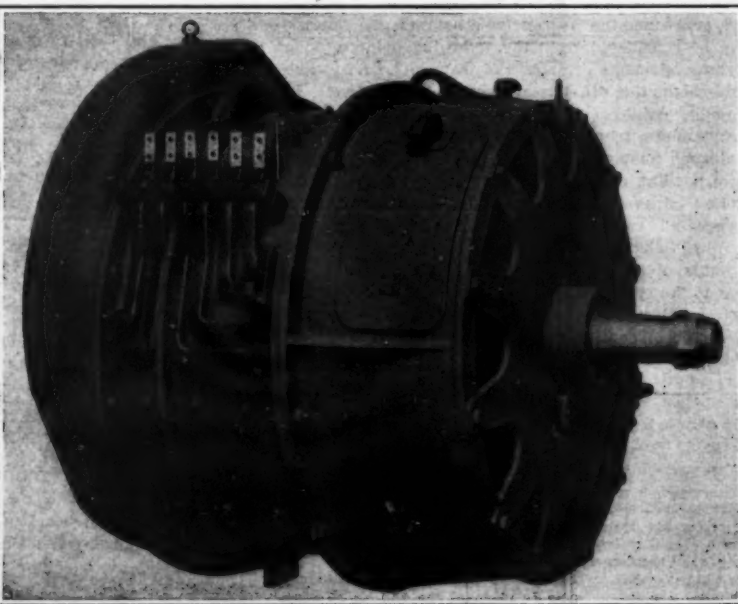
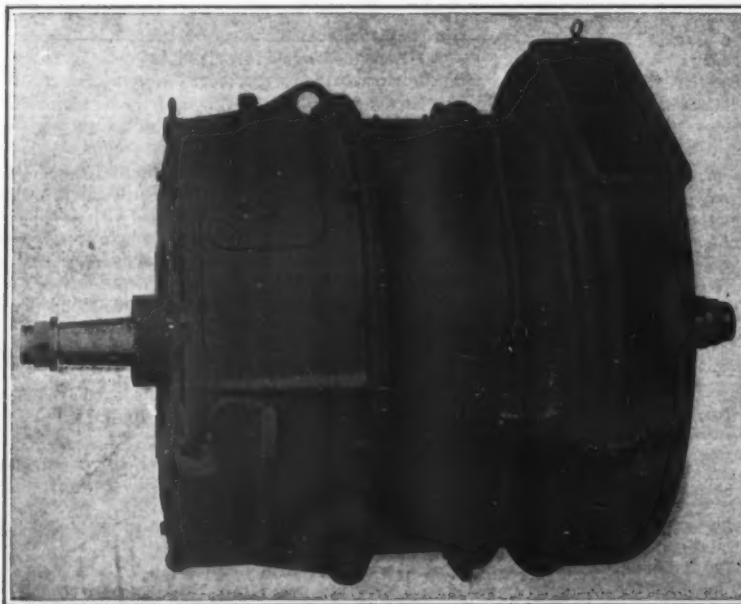
In an article in *Engineering* of May 2 last, Mr. J. Buchli described some electric locomotives built by Messrs. Brown Boveri & Co. and the Swiss Locomotive & Machine Company for the Swiss Federal Railways, and for operating on the Bernese Alpine Railway. As stated in the early part of that article, the authorities of the Swiss Federal Railways decided to have four trial locomotives built and tested before larger numbers were put in hand. Two locomotives of the four were supplied by Messrs. Brown Boveri, and were described in the article to which we have referred. The remaining two were supplied by the Ateliers de Construction Oerlikon, Switzerland, and it is the purpose of this article to give some description of these latter. As in the case of the Brown Boveri products, the mechanical parts of the locomotives were supplied by the Swiss Locomotive and Machine Company, of Winterthur. The Oerlikon locomotives have been delivered and have carried out their trials on the Lötschberg Railway.

The two locomotives supplied comprised one each of two different types, of which the chief dimensions are given in the following table:

	Singlephase	
	Type 2-6-2	Type 2-4-4-2
Voltage	15,000	15,000
Periodicity, per second	162/3	162/3

(Continued on page 158)

*From *Engineering* (London)



The 12-pole motors of the new electric Swiss locomotives. Lefthand view shows the ventilator

Aids for the Deaf*

Mechanical Devices to Remedy Defective Hearing and Why They Often Disappoint

By Prof. F. Womack, B. Sc., M. B.

THE question has often been propounded—why is it apparently not possible to remedy defects of hearing, especially such as are concurrent with advance of years, with the same satisfactoriness that defects of vision can be remedied by the use of spectacles? In answering this question, we shall be better able to understand the difficulty to be surmounted if we consider the difference of the two scientific problems.

Most of the difficulties or defects of vision are due, not to lack of sensitiveness of the retina, but to limited range of focussing power; and all that is necessary is to so deflect the path of the light by refraction as to cause the rays to diverge from some point within the restricted range of focussing. Had the defect been due to lack of sensitiveness of the retina, the problem would be as difficult of solution as that relating to hearing; in fact, the former would be virtually unsolvable, since the brightness of every image of finite magnitude is diminished by every optical contrivance employing reflection or refraction. The problem in the case of hearing is, how to increase the energy density of the sound waves reaching the observer—how to concentrate the vibrational energy of the wave motion, that the number of ergs per second per square centimeter may be sufficiently increased to reach the minimum necessary for audition. The energy density necessary for hearing by a normal person is surprisingly small. Dr. P. E. Shaw measured the amplitude of movement of the diaphragm of a telephone when this was only just sufficient to produce an audible sound, and found that this minimum displacement was of the order 0.7×10^{-7} (seven hundred-millionths of a centimeter, or three hundred-millionths of an inch). The air immediately adjacent to the telephone diaphragm would however not move backwards and forwards even to this extent, but as estimated by Lord Rayleigh would be approximately five times less, or 0.15×10^{-7} cm.

Lord Rayleigh has also investigated this same problem by two entirely different methods; one depending on the blowing of a whistle by a stream of air working at known power, the observer going so far away that the whistle is only just audible, and the second depending on the estimate of the rate of output of sound energy by a tuning-fork at the instant at which it ceases to be audible though still vibrating. The former method gave 0.8×10^{-7} cm., and the latter 1.2×10^{-7} cm. as the minimum amplitude of vibration of the air for audibility. The figures of Rayleigh are several times larger than those of Shaw, but taking the higher mean figure, say 10^{-7} of Rayleigh, this corresponds to an energy density of only 0.000041 ergs per sec. per sq. cm., or 1.3×10^{-7} ergs per c.cm. If we might neglect the existence of bone conduction of sound through the skull, and if we take the opening of the external meatus of the ear as about 1 sq. cm., then provided vibrational energy reach the observer at the rate of 0.000043 ergs per sec., or say 6×10^{-8} of a horsepower, the sound will be audible to a person of normal acuity of hearing. For sounds used in ordinary conversation this figure would have to be increased some ten times.

It is, however, a question not merely of collecting enough vibrational energy and conveying this to the ear of the person with defective hearing, but it is just as essential that the quality or timbre of the sound shall not be so far altered as to render the sounds unintelligible. Now in ordinary speech the consonants merely serve as momentary interruptions between vowel sounds, the interruption being produced at lips, teeth, or back of hard plate, the timber of the sound is that given by the succession of vowel sounds.

Much research has been expended in the study of the conditions for vowel-production, pioneer work being done by Willis and by Wheatstone. It appears from the present state of our knowledge that, to produce a vowel sound of given character, it is necessary that the sound shall contain from six to eight separate partial tones, each of definite pitch, irrespective of the fundamental tone to which the vibration of the vocal chords give rise. These partial tones are widely separated in pitch, and do not form a harmonic series. If, then, in any piece of apparatus designed to act by the principle of resonance it is possible for these partial tones and no others to be reinforced, there is reason to hope that such a piece of apparatus may leave the timbre of the vowel sound not materially affected, and

that it may therefore fulfil the second desideratum. This conclusion is arrived at by the study of the forms of manometric flames, and by sections of the depth of the indentations in the plate of a gramophone, and is borne out by the observation that the vowel sound emitted by a gramophone is entirely altered if the disc is run at a different speed.

It is, however, only right to say that there is an alternative theory of vowel quality, according to which

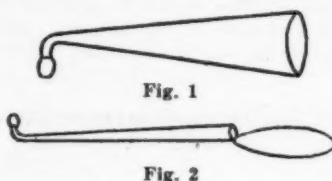


Fig. 1



Fig. 2

a given vowel requires the existence of partials of a prescribed order to be present, and not partials of fixed and prescribed pitch. To what extent this latter theory may be true (and according to Auerbach both characteristics must be fulfilled) it is apparently impossible that any resonator of fixed shape can satisfy the conditions demanded by this second theory.

In short, both quantity and quality of the sound heard must be taken into account in considering the efficacy of any instrument for hearing.



Fig. 3

For purposes of convenience the existing types of mechanical aids to hearing may be attempted classified, so far as there is any principle at all underlying their construction, under the following headings:

- A. Simple transmission tubes.
- B. Cone-shaped or tapering reflectors. When short these are called by various names, such as trumpets, cornets, auricles, etc.
- C. "Trumpets," i. e. a conical tube like the brass trumpet used on the Continent by the station master



Fig. 4

in starting a train, but with the narrow end usually doubled three times on itself.

- D. "Resonators," so called—bell-shaped, with a bent tapering tube attached at one point in the side.
- E. Instruments in which the idea of "bone conduction" is aimed at.
- F. Table instruments, in which no definite principle is aimed at, such as resonance, reflection, or conduction through a solid.
- G. Telephonic instruments.

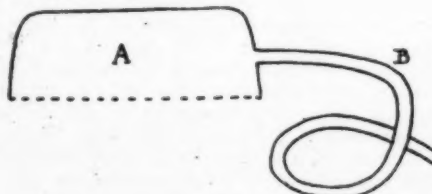


Fig. 5

Class A is familiar to every one in the form of the speaking-tube used from one room to another in a house. Provided that certain conditions are fulfilled, and especially that sharp angular bends are avoided, such simple instruments are of service for the purpose of ordinary conversation between two persons. The physical principle is merely that of continued reflection of the sound waves from the inner wall of the tube, with consequent prevention of spreading out of the wave front and diminution of the energy den-

sity with increase of distance. The law of reflection is immaterial, and the efficiency is but little affected by the bore of the tube, which may be attributed to conduction of sound also through the material of the tube (as in a wooden stethoscope) playing some secondary part in the process.

Before considering the next class, B, C, D, it may be as well to refer to the underlying acoustic principles, viz. reflection of sound waves and resonance.

All reflection of wave motion by a surface to an observer is fundamentally diffuse reflection; that is, however large or whatever the shape of the reflecting surface may be, every part contributes something to the energy reaching the observer. When we are dealing, however, with short waves, such as those of light, the outlying portions of the surface reflect waves that are mutually destructive, and the effective portion of the surface is so small that the energy is reflected strictly in accordance with the familiar law that the angles of incidence and reflection are equal. But with long waves, such as we have to deal with in sound, the effective part of the surface is not small, and all of the surface with which we have to deal contributes something to the sound ultimately heard. This is well illustrated in the case of reflection of sound by the wall of a house or the face of a cliff, or by the "sounding-board" suspended over a pulpit, or by the difficulty of determining whether a vehicle is coming from right or left along a street when the observer is in a side-street. The degree to which the problem is affected by the length of the waves, or, what is essentially the same thing, the pitch of the note, may be well illustrated by listening to the shrill ticking of a watch held in the hand, and noticing that if a postcard or book is held a few inches from the ear the sound of the ticking is no longer heard. But if the lower pitched ticking of a pendulum clock is employed the introduction of the book hardly reduces the loudness.

In class B, which may be suggested by Fig. 1, what little efficiency these instruments possess, and for the most part this is very little indeed, depends solely upon reflection; the source of sound, the speaker, being far away from the wide end of the cone. The inefficiency is due to the fact that the area of the reflecting surface is too small a fraction of the "effective" area appropriate to the long waves employed in speech. It is as if one were to endeavor to reflect waves on the sea by holding a small flat surface like a spade for them to impinge against.

If one realizes that the long waves of sound are diffusely reflected, and not reflected in accordance with the law of equality of the angles of incidence and reflection, one will understand the uselessness of all instruments that pretend to "focus" the sound waves to a point and then convey them by a tube to the observers' ear. See Fig. 2.

In Class C, usually known as trumpets, and illustrated in general design by Fig. 3, reflection, ineffective as it must necessarily be because of the smallness of the whole reflecting surface, is reduced to nil; and what little efficiency they possess can only be due to resonance. Now if one were to reverse the action of the instrument, and, unscrewing the nipple end, use the instrument with a suitable mouthpiece as a producer of sound, e. g. as a bugle, it would be realized that there is a very limited series of tones that it will emit; and similarly there is a very limited series of tones to which it will respond. The pitch of the lowest tone to which it resounds depends on its total length, and to some extent on the diameter of its trumpeted end, but it will be generally found that the fundamental tone of the instrument is considerably higher than that employed in speech. Apart from the natural raising and lowering of pitch during speech, a man's voice employs notes of about $\delta = 100$ vibrations per second as a mean, and the resonator for this would require to be about 42 inches long, though a shorter instrument would suffice for listening to a woman's voice. Moreover, as shown by Helmholtz and others, for the production of a vowel quality of tone, several partial tones are necessary, and the lowest of these is for most vowels much below the fundamental tone of the instruments used in deafness. Let one take, for example, one of the large shells of the type formerly used, on account of its pearl-like colors, for decoration, and hold it to the ear. It will respond to a very limited series of tones, the lowest of which will probably be about $b' = 490$ or $c'' = 523$, and the next an octave

*From Science Progress (London).

higher. These may be easily found by striking the notes of a pianoforte while holding the shell to the ear.

The fundamental defect therefore of Class C of instruments is that they reinforce only a few notes, and these of too high a pitch, and consequently the quality of the sound is materially altered; vowels—on which the character of speech almost solely depends—being entirely altered in timbre.

Class D, see Fig. 4, usually called resonators, are generally of the shape of a small bell, with one narrow, bent, and tapering tube leading from near the mouth of the bell to the external meatus of the ear. The inefficiency of these is not reduced by the addition of a more or less ornamental grille blocking up the mouth of the bell, although it is sometimes claimed that the grille has a "useful and necessary acoustical effect."

The writer of this article has recently examined nearly eighty instruments of different types, testing them not merely subjectively, but by two physical methods of extreme delicacy, the instrument being connected to an extremely sensitive manometric flame, and also to a drum membrane pendulum detector. Nearly all the instruments of classes B, C, and D were found to be virtually useless; it was only in class F that some slight improvement was obtained.

Class F constructionally does not differ from D. See Fig. 5. There is usually an air cavity A, short and wide, and resounding especially to one note of fixed but generally high pitch, connected by a flexible tube B to a monaural or binaural earpiece at the further end. The metal portion A is intended to rest on a table. This class of instruments depends principally on solid conduction, and requires that the table on which the receiver is placed should be of wood, not covered by a cloth. So far as resonance of the air chamber of the receiver plays any part in the mechanism, the criticism urged against the preceding classes applies, viz. that the resonant air-chamber is too small, and that its fundamental tone lies above the tones usually employed in speech.

On account of the complex shape the fundamental tone of the air-chamber cannot be computed, though it may easily be found experimentally; but that the dimension is in general too small may be judged from this, that to resound to the note $g' = 192$, a spherical König receiver would have to be 15 cm. diameter, or nearly 2 litres capacity.

With regard to class G, we have here a class of instrument dependent on the principle of the microphone, in which the energy of the incident waves may, by supplementing it by the energy of an electric battery, be increased any desired number of times, and the sound correspondingly intensified. The instrument is, in fact, a portable telephone-receiver and transmitter. The possibility of doing this completely satisfactorily depends on the facts (1) that the diaphragm of the telephone receiver being of fairly thin sheet-iron, and of considerable diameter, has an intrinsically low-pitched fundamental, (2) that the partial tones it possesses are almost unlimited in number and do not form a "series" 1, 2, 3, 4, etc., or 1, 3, 5, 7, etc., with wide intervals of pitch as in ordinarily vibrating bodies; but that the higher members of the group have tones lying so close together that the limited number of partial tones in the voice sounds are pretty certain to have their counterparts in those of the telephone diaphragm. There is a certain alteration of the timbre, in part due to the representation of these partial tones not being complete, but probably principally because the changes of resistance of the microphone receiver are not proportionate to the movement of its diaphragm, and as in the telephone receiver the consonants are imperfectly produced. Much improvement in this latter respect is doubtless possible by the employment of some of those principles used in connection with wireless telephony, and in fact much more rapid improvement in various form of apparatus would be feasible if the persons who devise them had a modicum of knowledge of physics, instead of being guided by pure empiricism.

In brief, of the mechanical aids so far devised, classes B, C, D, and E are of little efficiency, A is serviceable with the limitation that it can only be used for conversation between two persons, while class F is the most efficient.

Swiss Railways Extend Electrification

(Continued from page 156)

section Bevers-Filisur of the Rhaetian Railroads.

The section Sion-Brigue about to be electrified will be a continuation of the Simplon tunnel electric traction which was opened for traffic in 1906, with its northern exit at Brigue.

The electrified Berne-Thun line, connecting with the electric Berne-Lötschberg-Simplon railway inaugurated

in 1913, has been open for traffic since May, 1919. It provides excellent and frequent train connections between the Swiss Capital, the Bernese Oberland resorts and—in connection with the Lötschberg line—the Valais and northern Italy.

We show in Fig. 1 the new locomotives used by the Swiss Federal Railroads on the section Berne-Thun as well as the Berne-Lötschberg-Simplon line. They are each equipped with four single phase-alternate current motors, each of 450-horsepower. The electric parts were furnished by Brown-Boveri & Company, Baden, and the mechanical parts by the Swiss Locomotive & Machine Company of Winterthur.

The electrification works on the Bevers-Filisur line were completed by middle of April, 1919, and from April 16 the steam engines have been duly replaced by electric motors. The current is supplied by the Power Station of Bevers, which also has been furnishing the necessary energy for the Engadine lines electrified in 1913.

Oerlikon Locomotives for Switzerland

(Continued from page 156)

	Singlephase Type 2-6-2	Type 2-4-4-2
Horse-power at wheel rims.....	1,650	2,250
Draw-bar pull (1½ hour test), lb. 19,000		26,000
Maximum draw-bar pull, lb.....	30,000	40,000
Normal speed .....m.p.h.	31	31
Maximum speed .....m.p.h.	47	47
Weight of mechanical parts, tons	46.5	53.5
Weight of electrical parts, tons	44.5	54.5
Total weight, tons.....	91	113
Adherent weight, tons.....	58.5	80

Both classes of locomotives have a two-wheeled Bissell truck at the leading and trailing ends, but in one type three pairs of coupled driving wheels are placed at the center, while the other has two sets of two pairs of coupled wheels. It is unnecessary to describe both locomotives in detail, as in many features they are similar. We will accordingly deal mainly with the 2-6-2 type. The leading and trailing trucks are of the Bissell type and have a lateral play of 3 in. They are returned to their middle position by two plate springs. To ease the travelling of the locomotive, when running round curves, the driving wheels are also capable of a lateral play of 1 in. on each side. The locomotive is driven by two motors situated side by side and above the level of the cab floor.

Each motor shaft carries a pinion at each end, so that there are four pinions in all. The pinions gear with spur wheels carrying on their faces crank-pins which are coupled by a triangular-shaped frame. This operates the center driving wheel through a reciprocating cross-head block, while the outer wheels are connected to it by means of coupling rods. The pinions are connected to their shafts through flexible couplings giving elasticity of drive.

The main frame of each locomotive is built up of two longitudinal members made from 1-in. plate. The suspension is such that each carrying axle is connected by compensating bars to the adjacent motor axle. Further, the spur wheels, with their shafts, can be removed without dismantling the main suspension in any way.

The cab is divided into five compartments, a driving cabin being situated at each end, inside of each of which there is a transformer compartment with a motor section in the middle. The side panels are removable for the inspection or repair of the motors and transformers.

A very ingenious safety device is provided which will prevent accident to any one who attempts to mount on top of the locomotive when it is electrically connected with the overhead power line. There is a ladder giving access to the top of the locomotive which is locked with a whistle connected to the compressed air supply, which gives warning if an attempt is made to mount the roof with the pantograph collectors raised. The blowing of the whistle lowers the pantograph. Both power and hand brakes are fitted, there being 12 brake shoes in all. The braking effect is equivalent to 80 per cent of the adherent weight.

The two motors are able to exert 675 h.p. on continuous rating and 825 h.p. for 1½ hours. They are of the compensated series type, and each have 12 poles. Reversing is obtained by changing the direction of the excitation current, which operation is carried out by an electro-pneumatic commutator mounted above the motors. The double motor arrangement, which has been adopted mainly for mechanical reasons, necessitates a double control equipment in order to ensure a proper distribution of the power between the different driving axles. The arrangement incidentally is of advantage in reducing the weight and number of spare

parts which have to be provided. The system also permits of the employment of contactor control, the banks of 12 contactors for each motor giving a range of 23 speeds. Locomotives supplied by the Oerlikon Company to the Lötschberg and other railways are equipped with similar contactor control, and have been in successful service for a number of years. The control arrangements have been entirely successful. The contactors are controlled electro-pneumatically, or can, in case of need, be operated by hand.

There are two main transformers of the air-cooled type. Each is connected to its corresponding motor through a contactor in series with a current transformer and a self inductance. The current transformer supplies current to an automatic cut-out. In general the two circuits, formed each of a transformer and motor, are connected in series. A group commutator placed above the transformers permits, however, other connections to be made. Thus each circuit may be completely isolated from the other. This permits one to be cut out in case of breakdown, while the other may continue working. In this condition the locomotive may still develop full speed, but of course, with only half the normal tractive effort. Another connection permits one transformer to supply the two motors. In this case the locomotive develops normal tractive effort at half-speed. The high-tension circuit consists of the two pantographs with their disconnecting switches and over-voltage discharges, two disconnecting switches for the transformers, two current transformers, and two earthing connections.

The pantographs have a working range of height between 4.8 m. and 7 m. They are operated by compressed air, a hand pump being fitted for emergency use. The disconnecting switches can be operated from inside the locomotive, and are interlocked with the door of the high-tension cabin. These main disconnecting switches are of the oil-break type operated electro-pneumatically, and have automatic overload and no-voltage attachments. The various auxiliary equipment fitted to the locomotive consists of two air compressors, ventilating fans, and a motor converter set, connected with a battery of accumulators. All auxiliary apparatus is operated by a 100-volt circuit fed from the battery. The air compressors supply at 5 atmospheres to 7 atmospheres, and are started and stopped by an automatic regulator operating the turns of the pressure in the air receiver. A heating circuit of 500 volts is tapped by the main transformer, and is used for heating the water. The maximum current is 400 amperes. Multiple control is used so that the two locomotives may be driven together with one control.

The 2-4-4-2 type locomotive has in the main the same arrangement of gear and control as the one described above, and need not be dealt with in detail. This locomotive, however, is fitted with gear permitting recuperation when braking or running down hill. The electrical gear is arranged in both cases for a line voltage of 15,000, but transformer connections are fitted permitting operation at 7,500 volts. The 2-6-2 locomotive hauling a train of 200-7 metric tons on a gradient of 2.7 per cent accelerated from standing to 32 miles an hour in 150 seconds. Drawbar pulls up to 24,000 lb. were recorded. The maximum power exerted was 2,160 brake horse-power at 35 miles an hour. The 2-4-4-2 locomotive on trial handled a train of 304.4 metric tons (exclusive of the weight of the locomotive). A drawbar pull of 37,000 lb. was recorded.

Fusibility of West Virginia Coal Ash

THE troublesome formation of clinker which results from the melting of the ash constituents of coal when subjected to heat, has aroused an interest (among engineers) in the fusibility of coal ash, and the U. S. A. Bureau of Mines have therefore felt constrained to make a general survey of the subject.

The coal samples are ground to 60-mesh, placed in shallow fireclay roasting dishes and completely ashed in a muffle furnace at a temperature of 1,472° to 1,652° Fahrenheit. The resulting ash is ground to pass a 200-mesh sieve. To ensure that the coal is completely ashed, the ash after grinding is placed in fused silica capsules and ignited at 1,472° Fahrenheit for two hours, with a current of oxygen passing through the furnace.

The ash is then moistened with 10 per cent. dextrin solution and moulded into small pyramids with which the test is made. By proper adjustment of the gas and air in the furnace, the iron in the ash is reduced to the ferrous state, and from the conditions prevailing the lowest temperature at which clinkering may result is obtained.

The article includes a table giving the softening temperatures of coal ash from West Virginia coal, but this table is necessarily incomplete from lack of space, and the whole statistics will be published at a later date in bulletin form by the Bureau of Mines.—*Selig, Power.*

Water-Resistant Glues*

By F. L. Brown, Madison, Wis.

UNTIL comparatively recently, practically all glues used in joining wood were the more or less impure forms of gelatin obtained by extraction from waste animal products such as hides, skins, bones, horns, hoofs, fish parts, etc. These glues are either of the solid or liquid type. For use the former are soaked in the proper amount of water, heated to a temperature slightly above their melting point, and applied to the surfaces to be joined, which are then put under pressure. On cooling and drying the glue film gives a strong joint. Liquid glues are applied cold and harden in the joint on drying.¹

Although gelatin glues of good quality yield very strong joints, they are subject to the disadvantage of softening to the extent of losing their holding power when kept in contact with much moisture, whether in the form of water or of high atmospheric humidity. Attempts have been made to increase the water resistance of gelatin glues by the addition of certain chemicals, but, although some progress has been made, satisfactory results have not yet been obtained. The only way so far found to make such joints serviceable under humid conditions is to keep the water away from them by using waterproof coatings.

The vegetable glues, made by heating starch (chiefly cassava starch) and water, in the presence of alkali lose their strength as gelatin glues do when exposed to humid conditions and can be made waterproof only by means of protective coatings.

Glued joints in an aeroplane are frequently subjected to very severe moisture conditions, and hence water-resistance is usually a large factor in the choice of an aeroplane glue. The known high strength and dependability of gelatin glues made it advisable to use them for propeller construction rather than glues whose characteristics were not so well known, especially since it was found possible to apply waterproof coatings. But for many plywood parts of aeroplanes, waterproof coating is not practicable, so that the use of water-resistant glue becomes a necessity.

At present there are two types of these in use, one having casein as a base and the other blood albumin. These glues are water-resistant in the sense that the amount of water the dry glue films on the joints will take up is limited and the saturated glue still has sufficient strength to hold the joined surfaces together.

In order to control properly the quality of plywood glued with water-resistant glues and to develop glue production it was necessary for the Bureau of Aircraft Production to know how to make and use these glues. The Forest Products Laboratory of the U. S. Forest Service was therefore requested to investigate the subject. Research work was started late in 1917 and is still being continued. The following information is based on the results thus far obtained:

BLOOD ALBUMEN GLUE.

Blood glues are a very recent development, in this country at least. The few plants using them before the war had their own secret formulas, and there has been very little information published on the subject.

Water-resistant glue can be made from fresh blood and where a supply is readily obtainable from a nearby slaughter house this may be the cheapest way to make it. The desirability and convenience of using the fresh blood, however, are open to question. Blood is subject to rapid bacterial decomposition, and hence where it cannot be utilized at once, it must be treated with a preservative or processed and the dried blood albumin used.

The material ordinarily used for making blood glue is the black soluble albumen which remains after subjecting blood to a process for removing the fibrin and part of the haemoglobin or red corpuscles, and carefully evaporating to dryness. This material is not only cheaper than the albumin from which all haemoglobin has been removed, but has been found to give a stronger glue. It is stable over a reasonably long period of time, but the solubility gradually decreases with age. Since only the soluble portion of the albumin forms the essential glue-making material, freshly dried blood is more desirable. Loss of solubility likewise makes it impracticable to prepare blood albumin glue in the form of a dry powder ready for mixing with water.

HARDENING BLOOD GLUE.

Blood glue must be hardened by heating it to a temperature at which the albumin coagulates. This effect is ordinarily accomplished by the use of a hot press. The press commonly used is of the hydraulic

type with hollow platens heated by steam. Blood glue is chiefly suited to plywood manufacture. Heavier joint work can be carried out, however, by clamping together the glued surfaces and subsequently placing them in a dry kiln or chamber at the proper temperature until the blood is coagulated.

Albumin coagulates at temperatures above 162°F., but a temperature of about 212° is usually employed in the press. For glues containing much inert material, temperatures as high as 300° are sometimes used, but blisters are likely to result. A satisfactory pressure is about 150 lb. per sq. in. The time required for pressing depends upon the thickness of the outer plies; the thicker the plies the longer it takes for the heat to penetrate the wood and coagulate the glue. For 3/16-in. 3-ply material, 3½ to 4 minutes at 212°F. are sufficient. The action of blood glue in hardening is the same as that which takes place in the white of an egg on boiling.

WATERPROOF GLUE.

A waterproof glue can be made simply by dissolving blood albumin in water. The glue is improved, however, by the addition of a little ammonia and lime, and may be cheapened without great loss in strength by the addition of other ingredients. Too much lime must not be used, since it causes the mixture to set quickly to an unworkable jelly.

A very satisfactory blood glue² is made by soaking six parts of black blood albumin in eleven parts of water for at least 2 hours, then stirring and passing the mixture through a 30-mesh screen to remove undissolved particles. One-fourth part of ammonium hydroxide solution (specific gravity 0.90) and 0.18 part of hydrated lime are then stirred in. The lime is added in the form of a thick cream made by mixing the powder with a little water.

CASEIN GLUE.

Casein glues seem to have been known for a much longer time than blood glues, especially in Europe, but have not found any great use, so far as is known, until the last few years. During the war they have been used in American, British, French, Italian and German aeroplanes. Much more information is available in the chemical literature and old patents on this subject than is the case with blood glue.

Casein is a by-product of the dairy industry, obtained either from buttermilk or skim milk. Most of it comes from skim milk. The casein is precipitated by adding rennet, or acids, such as sulphuric or hydrochloric, or by allowing the milk to sour naturally, forming lactic acid from the milk sugar. There are many slight variations in the technique of the processes, so that the product obtained on the market is not uniform, the chief variation being in the ash content and the acidity. This variation frequently makes necessary slight changes in proportions in using different shipments of casein in a given glue formula.

Casein is very closely related chemically to albumin. It does not show such definite coagulation on heating; as in the case of albumin, however, certain chemicals have the property of causing its solutions to harden, forming jellies. Some of the casein jellies after drying will absorb only a limited amount of water. Casein glue is mixed at ordinary temperatures and the joints are pressed without heat until the glue has hardened, then they are dried down to the moisture content desired in the finished product.

Casein glues may be divided into two classes: (1) "Wet" glues in which the various ingredients are kept separate until the glue batch is to be made up for immediate use; and (2) "dry" glues, in which all the ingredients except the water are mixed to form a dry powder which can be kept until ready to use and then merely mixed with water.

A very simple but effective wet glue can be made using simply lime and casein, but it is open to the serious objection that its working "life" is only from 15 to 45 minutes. At the end of this time it has hardened to an unworkable jelly. The following formula for a wet glue has given very excellent results.³

100 parts casein	} Soak 15 minutes	} mix	} mix
130-280 parts water			
15-22 parts hydrated lime	} mix	} mix	} mix
90 parts water			
70 parts sodium silicate (water glass)			

The casein is soaked in water until thoroughly wet, the lime water is stirred in, and the sodium silicate added last. Stirring is continued until a smooth mixture, free from lumps, is obtained. The amount

of water in which the casein is soaked as well as the quantity of lime used depend upon the composition of the casein, particularly upon its ash content. The life of this glue is usually about 8 hours.

In mixing dry glues, the powder is stirred into the proper amount of water until a smooth liquid results. With all casein glues, it is important that the mixing be done thoroughly so that the casein will be completely dissolved and the glue free from lumps. For the purpose a power cake mixer has been found to give very satisfactory results.

COMPARISON OF BLOOD AND CASEIN GLUES.

Blood glue has the disadvantage, as compared with casein glue, of requiring hot pressing, which limits the output of the press and makes it less easily used for such joint work as gluing propeller laminations. Blood glue is not readily obtainable as a dry glue, whereas casein is. Casein glue has been somewhat less expensive, but a considerable amount of cheap inert matter can be introduced in blood glue without serious loss of strength. In the matter of water-resistance, blood glue possesses a slight advantage. Although blood and casein glues are more expensive than vegetable glue, their water-resistance will give them a wide application in the future. They are both in the early stages of development still, and much improvement in both cheapness and water-resistance may be looked for.

Illuminating Devices in the Great War

(Continued from page 155)

The results of this calculation show how extremely high these temperatures are; 8549°K. is a temperature above that of the sun and there are only a few stars which exceed it in value. It may be well to give here a short table of some of the data needed in such a calculation as that carried out above. The substances given are among the most common ones met with in practice.

Thermal Data.

Substance	Molecular Weight	Molecular Heat of Formation.	Molecular Specific Heat.
		Large Calories per Molegram.	
Ba(NO ₃) ₂	262	229	..
Ba	136	...	9.8
BaO	153	133	10
BaCO ₃	197	286	21
BaSO ₄	234	344	25
BaS	169	103	12
KNO ₃	101	119	..
K	39	...	6.5
K ₂ O	94	97	17
K ₂ CO ₃	139	279	30
K ₂ SO ₄	174	342	33
K ₂ S	110	104	18
Al	30	...	..
Al ₂ O ₃	102	393	22
Mg	24	...	6
MgO	40	143	10
MgCO ₃	84	270	22
MgSO ₄	120	301	27
S	32	...	..
N ₂	...	...	4.8

FUTURE FIELD OF DEVELOPMENT.

The illuminating shell is still in its infancy. The possibility of applying real science to these problems is limitless. The reward will surely be there for those who are successful. These shells have now been recognized as a necessary auxiliary of a field army and as time goes on greater uses and wider fields of usefulness will present themselves. It is the writer's one desire to create an interest among the engineers and chemists of this country in these problems through the presentation of the present status. If this is accomplished, even in a small degree, by these articles the writer will be fully repaid.

Aluminum Soldering

THE scarcity of copper in Switzerland has had the effect of causing aluminum to be used as a substitute. The greatest difficulty in using this material lay in the impossibility of soldering it.

Aluminum solders have now been produced, and they should be selected according to the nature of the aluminum or aluminum alloy that is to be soldered.

Alut melts at 280° C., alufix at 210° C., tachyot at 240° C., and magnalot at 236° C.

These solders combine with the aluminum so as to form alloys at the point that is soldered, whereas solders used hitherto only stuck to the surface.

The parts to be soldered are heated out of contact with the flame until the solder flows thin, and the parts to be soldered are then pressed together, warmed again, and painted with solder round the edges.—*Schweizerische Elektrotechnische Zeitschrift.*

*From *Chem. and Metallurg. Engin.* (New York).

²For a bibliography on Glues see *Chem. and Metall. Engineering* August 1, 1919, v. 21, p. 138.

³Government patent in the name of S. B. Henning, Forest Products Laboratory, applied for.

⁴Government patent, U. S. No. 1,293,396, granted S. Butterman, Forest Products Laboratory, Jan. 14, 1919.

A 200,000-Year-Old Summer Playground

THIS is the time of year when the thoughts of most city dwellers are directed vacationward, and they are beginning to picture pleasingly the cooling breezes and the pleasures to be found at the various beaches along out Atlantic and Pacific Coast lines.

The oldest of all our still popular summer resorts is Long Branch, New Jersey. Back in the days when our great grandfathers and mothers were children, many of them were taken by their fond parents, during the summer months, to Long Branch, as years ago it was a fashionable resort and it has managed to this day to maintain its popularity.

In the early part of the administration of President Grant, it became popularly known as the "Summer Capital" of the United States, President Garfield died in Francklyn Cottage at Elberon, a section of Long Branch, and a couple of summers ago, President Wilson spent most of the summer enjoying the cooling sea breezes there.

While it is well known that Long Branch has been to the forefront for many years as a popular summer resort, very few realize that it is probably one of the oldest places of this nature in the United States, with a history of perhaps 200,000 years. Recent discoveries there, however, of a most interesting nature, go far to prove this.

One day while bathing in the surf, Dr. A. R. Ledoux of New York suddenly jumped on something very hard. The Doctor was hurt physically as well as in feelings, and he determined, at low tide, to investigate what had caused his mishap and spoiled his bath. Digging in the sand at the location of the accident he came suddenly upon a curiously interesting collection of fossil bones. One of these was the skull of a walrus, the second a fragment of a mastodon and the third was the bone of a ground sloth.

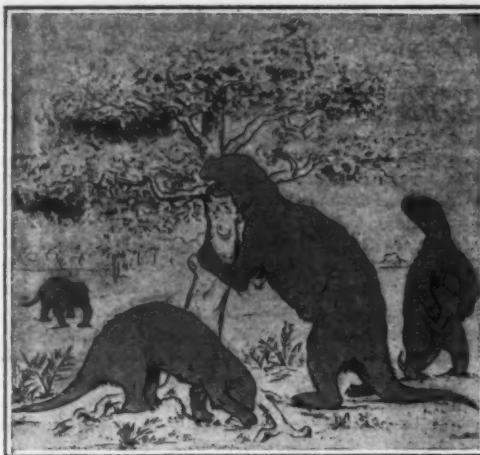
This heel-bone, for such it was, upon careful examination proved to be of enormous size, measuring over 15 inches in length, and weighing, in its semi-petrified condition, 20 pounds. While Dr. Ledoux discovered that the bone was encrusted with barnacles and small oyster shells, it did not show any evidences of erosion, and apparently had not been transported any considerable distance. The animal to whom it belonged probably died, if not on the exact spot, within a short distance of the place where the bone was found.

As the ground sloths flourished during the Pleistocene or Glacial Period, it is evident that Long Branch must have been inhabited then. They were fearsome creatures of gigantic size, these sloths, larger than any existing quadrupeds except the elephant. Their hind legs were very massive, as was the tail, which apparently helped to support the animal when he reached up after the leaves of trees, upon which he fed. Remains of ground sloths abound in South America, and are not uncommon in our own southern states, but this bone seems to mark about the northern limit of their range. The genus *Megatherium*, the largest of the ground sloth family to which the discovered heel-bone is believed to belong, has not been previously recorded as occurring north of Georgia. It is interesting to note that the *Megatherium* was the first fossil skeleton ever mounted. Nearly two centuries ago, a Spanish colonist in the Viceroyalty of Buenos Aires—now the Argentine Republic—discovered the skeleton of a huge animal in the River Luyan, a few miles from the city. The skeleton was sent to Madrid, and later mounted. It is still to be seen there, in the Royal Museum. It was the great Cuvier who recognized the relationship of this animal with the three sloths. It was he, also, who named it *Megatherium*. Since then, numerous skeletons of these animals have been recovered.

Dr. Ledoux's discoveries at Long Branch have recently been placed upon exhibition in the American Museum of Natural History, New York City, where they have attracted considerable attention from scientists.

To the layman what is probably most interesting about these recently found fossils is the fact that from them it is quite possible for science to reconstruct perfectly the life on the beach, at Long Branch 200,000 years ago, when man was there to see it; the first real American man, and what he saw was such an amazingly odd collection of strange creatures, that they must have kept the primitive Long Branch summer resident very thoughtful and most thoroughly amused, as he lay in the sun safely hidden in some corner, behind a sand dune, while his wife remained at home attending to the preparing of supper and the milking of the giant sloth, perhaps the identical one whose bones were recently discovered; for while the animals were fear-some to look upon, they are believed to have been harmless and to have been domesticated.

As he watched, Mr. Primitive American may have



Pen-line restoration of group of sloths shown on our front page

seen tramping down to the surf, great red-haired mammoths, droves of horses of most varied species and ranging in size from our smallest burros to the largest draught horses, fierce little peccaries with long, twitching noses, very extraordinary looking creatures with the necks of giraffes and heads of camels; bears as large as oxen, and wolves as small as pigs. Doubtless, he crept closer to his shelter as a huge brown cat, big as a grizzly with a long curved fang shining on each side of his mouth, noiselessly slunk by. After having viewed this panorama of a world of strange monsters, to his heart's content, he probably slipped back to his summer bungalow, as the sun was setting in the west, to find the milking over and the domesticated sloth—twenty-five feet long from tip to tip—safely tethered up for the night and the equivalent of the milk from ten good Jersey cows steaming in the milk pails; or whatever receptacle they had in those days to hold it in.

All these things, so strange to us, would have seemed perfectly natural to the Pleistocene American, enjoying his summer vacation by the sad sea waves. Could he have been touched with clairvoyance and in a dream have beheld the same beach this summer of 1919 A. D. filled with men and women of varying grades of grace and beauty and in varying hot weather costumes and breezy bathing suits, a hydroplane or two buzzing over the breakers, the great steel pier stretching out into the ocean, launches skipping hither and yon, or at night the electric lights blazing, he would have awakened as from a night mare, calling loudly for help.

The Long Branch summer resort in Pleistocene time would have had to, for safety's sake, build his cottage much farther inland than at present. In those days the beach was fully 70 feet below its present level, caused by the weight of the ice extending entirely across the continent and well southward toward the present location of the Gulf of Mexico. The depression caused by the weight of the ice was so great that it increased steadily northward, the St. Lawrence Valley being 600 feet lower than at present. In consequence, salt water extends up the Hudson and on as far as Ottawa, covering Lake Champlain. It is for this reason that the museums contain fossils of walruses, primitive whales and seals found in the rocks along this area, as well as at Long Branch and vicinity.

The reason that Long Branch was such a favorite summer resort for man and beast in prehistoric times is quite clear as during the long reign of the continental ice sheet northern animals were naturally forced to forage farther and farther southward for food, so that there is nothing perplexing in finding their remains on the northern coast of New Jersey. It is evident, however, that food was somewhat more abundant in the vicinity of Long Branch than farther inland, since the New Jersey coastal plan is so productive of so many varieties of skeletons.

At Long Branch mastodons, a fragment of the remains of one of which was found by Dr. Ledoux, were found together with those of the true elephants. The mastodon differed, however, from the elephant in having shorter legs, a lower and more flattened head, with smaller and simpler grinding teeth, lower crowned and rooted with three or four high, transverse, enamel covered crests without cement. The tusks were similar, but the mastodon had a single small tusk concealed in the lower jaw; a remnant left from an ancestral type which bore two sets of large tusks, one set in the upper and the other set in the lower jaw. He was some beast this mastodon who came to the beach at Long Branch to sniff the ocean breezes and enjoy the juicy foliage of the low branched trees which grew along the shore.

Supposed Effect of Sunlight on Water-Drops

G. H. BRYAN, in a recent issue of *Nature* (London), asks: Is it not the fact that sunshine causes a kind of "greasiness" which makes drops of water roll up when in contact with glass instead of spreading uniformly over the surface? I have frequently been troubled with this action when endeavoring to mount diatoms, and it is only recently that I have observed that it comes on as soon as the sun begins to shine, and that when the operation is performed in dull weather the difficulty does not arise. In clearing the diatoms from flocculent matter my practice is to rock the material from side to side in a shallow dish, dragging the diatoms into lines and rolling the dust and dirt off into lumps that can be sucked up with a syringe, but this process fails in sunshine owing to the diatoms floating. The evolution of a thin film of gas or vapor on the surface of the glass is a suggested explanation.

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